Bindery.

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The first irrigation by sun-power.

Scene at one of the irrigation canals.

SUN-POWER DEVELOPMENT IN EGYPT.—[See page 37.]

The Sinking and Lining of Shafts*

The Avoidance of Heavy Fixed Pumping Expense After Completion of Mines

By Francis Donaldson

When mining was begun in America, timber was cheap and plentiful, the deposits of virgin coal and ore were widely distributed and could be reached at no great depths, and the development of the rectangular timbered shaft was the natural result. Nowadays shafts are becoming deeper, mining installations more and more expensive and mining men are beginning to think they could possibly get better results by a partial return to European methods, and by the use of permanent linings. European shafts are generally circular, about twenty feet in diameter, and where the rock is moderately dry they are lined with brick, excluding the water that may occur in the fissures. As the shafts are sunk, and at intervals of about seventy-five feet, iron curb rings are placed as follows:

A cast iron ring made of sections bolted together with a groove or gutter on the inside (see Fig. 1) is placed in a notch cut in the rock. With this curb as a foundation the brick lining is built up to the ring above. As a rule the brickwork is built from a staging or platform suspended in the shaft in such a way that the sinking bucket can go up and down without interference. The lining is placed rapidly, as many as 3,000 bricks a day being laid by one man. The water that comes in through various seams in the rock is drained through passages in the curb ring to the gutter and conducted thence to a pipe in the shaft running down to the pump. The interior of the shaft is thus made absolutely dry and none of the water can fall into the shaft and interfere with the operation of the cages.

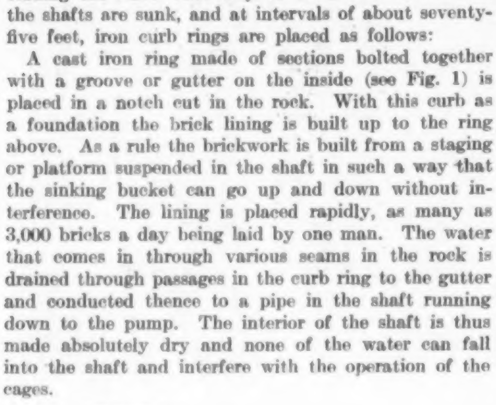


Fig. 2.—Sections of German type of tubbing made with internal flanges and connected by heavy bolts.

Where the rock is very wet the Europeans do not believe in pumping and keeping 3,000 or 4,000 horse-power in boilers to run pumps, so they use a shaft lining made of cast iron plates, sometimes as much as 2½ inches thick; this is very heavy of course, but effective. There are two types of plates or "tubbing," the German and the English. The sections of German tubbing (Fig. 2) are made with internal flanges and are connected by heavy bolts; the English tubbing sections have external flanges and are so constructed as to lock together without bolts or gaskets (Fig. 3) and are made watertight by wedging. The English sink straight through the wet rock into an impervious stratum and then set a curb ring upon which the regular tubbing is built up.

In 1838 the Murton shafts were sunk and there they handled 9,300 gallons of water from a depth of 450 feet where the impervious rock began. This is a greater quantity than we are able to handle in sinking in this country to-day with all modern appliances. It is generally known that the Europeans are away ahead of us when it comes to difficult mining propositions.

The Kind Chandron process has been developed to bore a shaft 15 feet in diameter from the top to a depth of 600 or 700 feet, to line it with cast iron tubbing and to seal it to an impervious stratum without a man going down into the shaft. The Europeans have also evolved a sinking drum system similar to our caisson method but on a more extensive scale. They sink a circular masonry caisson for 50 or 60 feet, building into the upper part a cast steel reaction ring, then build up circular cast iron tubbing with an outside diameter slightly smaller than the inside diameter of the caisson. From the bottom to the under side of the reaction ring a heavy cutting edge is provided. Powerful hydraulic jacks are placed between the reaction ring and the top of the tubbing, and the whole thing is jacked down, rings being added and the material being removed with a grab bucket. In that way they have penetrated five or six hundred feet in quicksand without anybody going down into the shaft. In this country when we go down 150 feet without anybody going in the caisson, we think we have done a particularly remarkable piece of engineering.

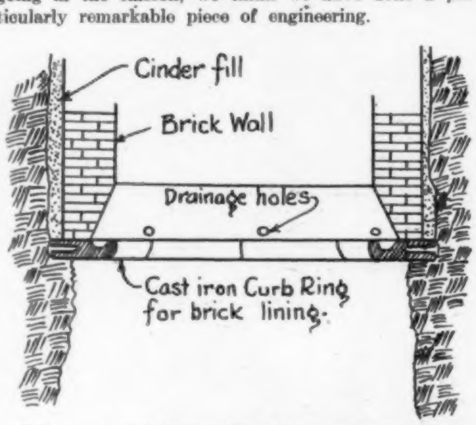


Fig. 1.—A cast iron ring with a groove on the inside is placed in a notch cut in the rock.

Brick or cast iron will not wear out; they are safe against fire, and in a long-lived mine are cheaper in the end than less permanent linings. On the other hand they call for a circular shaft, and in a shaft with several compartments rectangular construction is much more economical and includes less waste space than any other. In Europe the development has been largely due to the geological conditions. The Europeans have been forced toward their methods by the fact that the coal and the minerals are all deep down; they have had to go down through great depths of marl and limestone. Ninety per cent of the total footage of shafts in this country is in solid rock, and our problem is to meet the European requirements of safety, permanence and the exclusion of water without going to the great expense that they are put to in lining.

In pursuance of this idea a number of mining companies in this country have sunk shafts and lined them with concrete. The pioneers in this field sank two elliptical shafts in West Virginia about 200 feet deep and lined them with concrete. About three months after the mine started operation there was an explosion which wrecked the mine and killed eight or ten people, but the shafts were not injured in any way, and the operation of the cages was not stopped for an hour. They were able to go right ahead and proceed with their work of rescue and the rehabilitation of the mine itself.

It is only lately that the European requirement for the exclusion of water has been met, and that has been done on the Catskill Aqueduct. The condition has been met by cement grouting. The company who took charge of the work had a contract for the Rondout Siphon, which was a deep circular pressure tunnel under the Rondout Valley. The tunnel was about 5 miles long, and it was expected that they would meet considerable water. They did not, however, except in one shaft which was put down on a fault between limestone and conglomerate; great quantities of water were encountered here. This shaft was sub-let to a Pennsylvania contractor; he struck about 1,500 gallons of water per minute, put in all the pumps he could get and could not do anything with it. The shaft had reached a depth of 350 feet when it stuck. There had been a lot of water coming in on the side of the shaft (Fig. 4), a rectangular construction shaft by the way, lined with timber, and when the sinkers struck two or three more fissures in the bottom and got still more water it was the last straw and it broke the back of the pumps. Mr. John P. Hogan, a Division Engineer of the Board of Water Supply, then suggested that cementation be tried, and it was tried there for the first time in this country. The shaft was full of water, so they put in a platform as low as they could, installed a diamond drill, and drilled six 90-foot holes in the bottom of the shaft. They pumped them full of cement grout, forcing it through the diamond drill casings. Before they went much farther they encountered another leak of about 750 gallons a minute; as they drilled the bottom the water poured in through the machine drill holes they were going to shoot. So they simply plugged up those holes, then removed the plugs one at a time, drove in pipes connected to a grouting machine, pumped grout into the holes and cut the water off that way. By that means they were able to reduce the flow until they could put in a permanent pump station and handle the water.

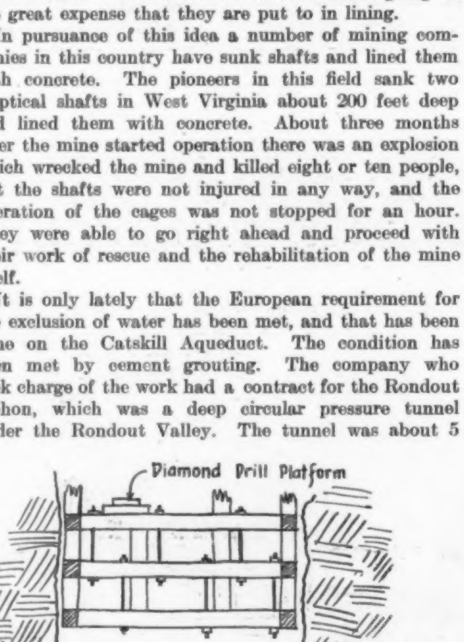


Fig. 4.—A rectangular construction shaft lined with timber.

The next shaft on the aqueduct where water was encountered was Shaft No. 4 (which I had charge of) in New York city, Borough of the Bronx. We went ahead and made good time until we got to a depth of about 100 feet. We were then drilling into the bottom when we struck a stream of water of about 150 gallons a minute in the first hole we drilled. We plugged that with a hard wood plug and cut the water off, drilled another hole and got the same flow and so on all around the shaft. We drilled 12 sump holes, all pointing in, and got water in all of them but two. We saw there was no use pumping them and we got ready for grouting. As soon as each hole cut the water bearing seam we plugged it, as stated above, with a tapered wooden plug. After all the holes in the sump had been drilled and plugged in this way, we made the grout connections one at a time so as to restrict the flow of water into the shaft. Each connection is made with a piece of 2-inch or 2½-inch iron pipe about three feet long. This is threaded at one end and given a long taper at the other. The tapered portion is made rough on the outside by nicking it with a chisel. A heavy iron "stop-cock" is screwed to the pipe, the tapered end is wrapped in several thicknesses of burlap, the wooden plug is then removed from the drill hole and the tapered pipe driven in, the stop-cock being left open. This is the most exciting and wettest part of the job. After the pipe has been driven in hard the stop-cock is closed.

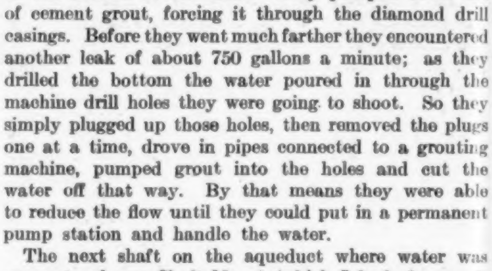


Fig. 3.—Sections of English type of tubbing have external flanges and lock without bolts or gaskets.

In this case we put connections in all the wet holes before grouting. The grouting machine or tank used on the Aqueduct was the Canniff machine (see Fig. 5) in which the grout is mixed by air. It is built like an air lock with a door on the top through which cement, sand and water are introduced, a 2-inch discharge opening in the bottom and air connections top and bottom. The discharge opening is connected to the grout hole by a heavy rubber hose. Another 2-inch stop-cock is placed at the outlet of the tank and a 2-inch by 1-inch tee is placed between the hose and the cock attached to the pipe in the drill hole. Into the side opening of this tee a 1-inch stop-cock is screwed.

The machine is taken to the bottom of the shaft, is connected to one of the holes and is also connected to the high pressure air supply. The 2-inch stop-cock on the machine is closed and the other is opened. The door in the top is opened, a sack of cement, three or

*Paper read before the Engineers' Club of Philadelphia, and published in its *Proceedings*.

four buckets of water, and, if the cavity to be filled is large, a sack of fine sand, are poured in, the air connection at the bottom is opened and the air allowed to bubble through and mix the grout. Then very quickly the door is closed, the lower air connection is closed, and the discharged connection and the upper air connection are opened and the air enters and drives the grout into the cavity. A man stationed at the 1-inch stop-cock keeps opening into a crack; when air shows instead of grout he closes the 2-inch stop-cock and the machine is recharged. If the cavity is open the charge is pushed in in three or four seconds, and by working continuously over a thousand batches can be placed in twenty-four hours.

In one hole on the Aqueduct we put in 4,000 sacks of cement before we got the fissure filled up. In Shaft No. 4 we put in about 100 in the first fissure. A little farther down in this shaft we encountered a layer of sand. The rock is folded very much; The sand was formed by the crushing of the rock due to the folding, was pretty fine and was carried up out of the drill holes by the water. Grout will not permeate sand and we had to continue drilling holes and pumping in grout, boosting the pressure at the end from 100 to 400 and 500 pounds to the square inch. We tamped that sand so full of cement that when we sunk through it it was compacted like sandstone. We found big balls of grout when we cut through it, some as big as a man's fist and some as big as his head.

The most interesting piece of grouting was done on the Hudson Siphon, which, as you know, is a deep siphon tunnel under the Hudson River; 14 feet diameter inside the concrete lining, and at a depth of 1,100 feet below tidewater. There was practically no water in the rock and the shaft sinking was done by the city forces. When they got to the bottom they concluded it would be cheaper to turn the job over to a contractor. On the east side of the river the city had driven 200 feet of tunnel through perfectly dry rock when they broke into a stream of water which flowed 300 gallons a minute. They struck it at night, and the shift boss shot his holes and broke away all the rock that should have been there to fasten the grout connections to. When we got the job we saw the next thing to do was to build a concrete bulkhead. We boarded up the face and put in 8 feet of concrete across the full tunnel section (at this point a top heading 7 feet high and 14 feet wide) and then reinforced it with rails. The concrete was mixed 1 : 2 : 4. We let the concrete set for a week and then started grouting. Grout pipes were put through the bulkhead, terminating in the fissures. At an elevation of 1,100 the hydrostatic pressure is 500 pounds per square inch, and we had hard work to force in any grout against it. We had eventually to raise the pressure to about 1,000 pounds per square inch, and to do this we had to use a high pressure plunger pump and pump water in on top of the grout in the tank. We put in two carloads of cement into that hole, and after it was set up for a week we shot the bulkhead out and went ahead with the tunnel.

The contractor for the lower end of the City Tunnel in New York has encountered a good many streams of water at depths up to 500 feet, and has grouted them successfully.

Where we met the sand bed in Shaft 4 we were unable to get the water entirely shut off and we had to rely on the concrete lining to get the shaft entirely dry. In good rock as in the Husdon Siphon a concrete lining is not needed in order to cut off most of the water because if you drill into the seams you can grout them

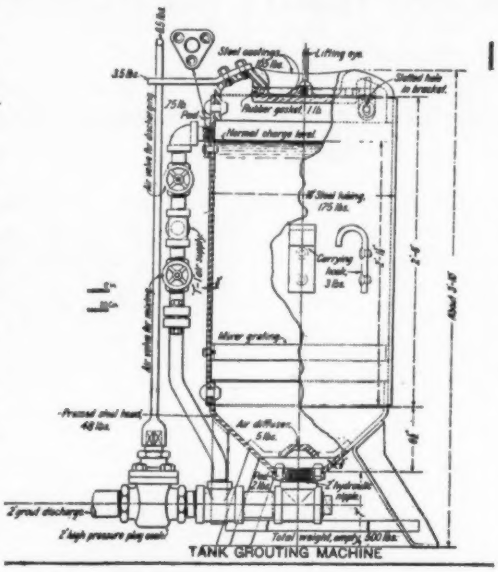


Fig. 5.—Grouting machine or tank in which the grout is mixed by air.

off. On the other hand if the rock is very much fissured it is practically impossible to grout it. When this is the case it is necessary to design a concrete lining strong enough to withstand the total water pressure that can come against the outside. In the case of an elliptical shaft that lining has to be thicker on the sides than at the ends; you can figure the stresses on the concrete if you are a good mathematician. We have found that 1-2-4 concrete 18 inches thick in a 14-foot tunnel will stand 600 pounds to the square inch. Anything higher than that broke it.

If you met a little stream, just a few drops a minute, a pipe must be set in opposite that stream and the water led through the lining. After this concrete has set up two or three weeks and got good and hard you connect the grout machine to this pipe, drive a little grout in and stop the water. It is absolutely impossible to stop water coming through concrete when it is soft. You have to provide a drain until it sets. In one case we overlooked a small spring and after we had concreted about 60 feet of shaft above it, we noticed the forms bulging over an area of about 10 feet square. We found that the accumulated pressure from the little spring had pushed the lining out over this area and we had to cut it out and replace it.

The question of a water-tight lining brings up the shape of the shaft. The shaft with the maximum area and the minimum lining is of course circular and this is by far the cheapest shaft to sink. That was brought out on the aqueduct. All the construction shafts at first were made rectangular and lined with timber while the waterway shafts were made circular. On the Rondout Siphon shafts we started out with the idea that the rectangular shafts would be easier than the circular, but it was the other way. When we started the first circular shaft we did not do much the first month. The last month we made 138 feet. The next siphon we moved to we had the same gang, and they knew how, and jumped the progress up to 170 feet in one month in shale. The same gang was then moved across the Hudson River to a granite shaft and we made 183 feet, which is the American record.

The way it was done is this: The drilling is all done on one shift. Enough drills are put into the shaft so that all the holes in the round can be drilled and the sump loaded and shot in eight hours. The other two shifts clean out the shaft and get it ready for the drilling shift the next morning. We drilled 33 holes to a round.

The same method is used in South Africa on rectangular shafts, but in this country it has not been successful in this type. I have tried it in four shafts and it would not work. However, in circular shafts we tried it and made it work.

I mentioned the rectangular construction shafts being slower to sink than the circular. In South Africa they hold the world's record for sinking and the shafts there are rectangular. In this country most rectangular shafts are about 12 feet by 26 feet and about ten to twelve men are carried on a shift. There will be two or three drill runners, three helpers and about six muckers. In South Africa they use 35 to 40 Kaffir men on a shift in a shaft of the same size.

Wherever the entire area of a circular shaft can be used, as for ventilation, a circular shape is best. Where this is not practicable, as in a hoist shaft with several compartments, the best plan is to cut the ends off the ellipse adopted in the case referred to above, and to make a compromise between an ellipse and a rectangular out of our circular arcs. In dry or moderately dry rock the concrete lining need not be over 15 inches to 18 inches thick, but in wet and seamy rock it must be thick enough to resist the hydrostatic pressure after the shaft is lined.

In New York city lately the contractors have been putting in as high as 25 to 30 feet of concrete in a day in a 14-foot circular shaft, and in six days, including getting started, putting the forms in and taking them out again, they will put in 100 to 120 feet.

The cost of a concrete lining is greater than the cost of a timber lining by just about the cost of the cement. As a rule, concrete outside the cost of the cement can be put in for the price of the timber; you have to pay for your cement and you have a permanent lining.

By a comparatively small expense and proper preparation, it is possible to make a water-tight shaft and a safe shaft with no delay; we do away with the expense and danger of handling big quantities of water from shafts while they are being sunk, and we do away with the heavy fixed expense of pumping after the mine is completed.

Wooden Water-Pipes

A short time ago there was some interesting correspondence in the *Times* on the subject of old wooden water-pipes. It began with a letter from a correspondent who had noticed that in Oxford Street a number of hollow tree trunks had been dug up, and who made the very sensible suggestion that a specimen of these ancient pipes might be preserved in the London Museum.

The secretary of the Society a few days later drew attention to the offer by the Society of a gold medal in 1804 for the discovery of "a substitute for the elm pipes now in common use for the conveyance of water." This offer was continued until 1816, when it was discontinued, probably because there were no applications for the prize.

A very full description of the wooden water-pipes will be found in Rees's Cyclopædia (Edition 1819). The article on "Pipes" speaks of these wooden pipes as being the usual and commonest means for conveying water in mains, lead pipes being used for domestic supplies, and iron pipes being referred to as coming into use. "Within the last few years immense quantities of iron pipes have been laid in all parts of London for the conveyance of water." At first there was, it is stated, great prejudice against their use, and the unreasonable nature of such an objection is very sensibly set forth by the writer of the article.

Reference is made to the Society's prizes, and the method of boring the trunks, by a hand auger or by mechanism, is described. The various lengths were socketed together by a spigot joint, the tapered end of one length being let into the coned out end of the next length. The joint was naturally imperfect, and there was much leakage.

The first letter to the *Times* was followed by a number of others, in which a good deal of information was given about these pipes, perhaps the most interesting being one from "Master" George Pollock, who said that he remembered such pipes being laid down in the early "thirties" of the last century. Mr. Pollock is now in his ninety-third year.

Mr. J. W. Ford wrote that in 1816 the Governor and Treasurer of the New River Company applied to Mr. Vansittart, the Chancellor of the Exchequer, when the iron trade was greatly depressed, for assistance to enable them to substitute iron pipes for the old elm ones. The Chancellor gave them a letter to the Bank of England, authorizing a loan of £100,000, on the condition that the money was to be expended in iron from the Staffordshire foundries. Mr. Ford also mentioned that extraordinary opposition was made to the substitution of iron for wood pipes, one of the objections raised being that the water would produce cancer.

Some further information on the subject has been obligingly furnished to the writer of this note by Mr. W. B. Bryan, the Chief Engineer of the Metropolitan Water Board, who thinks that it is almost impossible to say when cast-iron pipes were first used on a considerable scale for waterworks purposes, but he is satisfied that it was very early in the nineteenth century. The East London Waterworks Company commenced to use cast-iron pipes immediately after the incorporation of the company in 1808. This company had taken over the West Ham and Shadwell works, and the latter companies supplied all their water, as far as Mr. Bryan has been able to ascertain, through wooden pipes; but the East London Company laid down nothing but iron from the year 1808. The New River Company commenced to use cast-iron pipes about the same time, and up to that time they did not profess to serve above the ground-floor level of the houses, because their pipes were then of wood. But after that date iron pipes were used, and in the year 1816 the iron mains were charged regularly throughout the night, and great benefits arose by reason of the substitution of iron for wood. In the year 1821, Mr. Thomas Simpson, the engineer of the Chelsea Company, stated before a Royal Commission that they had laid down very many iron pipes, and that they were gradually changing the wood for iron. The higher pressures to which water was pumped by the engines of the East London Company in 1807 and 1808, and about the same time by the New River and other companies, necessitated the abolition of the wooden pipes, and Mr. Bryan thinks that for more than eighty years past the use of such pipes has been discontinued for the conveyance of water under pressure in London. It may be taken as practically certain that the old wooden pipes now occasionally dug up in various parts of London, were left *in situ*, and became "dead" as soon as the connection to the new iron pipe had been made.

It may be interesting to note that there is a casual reference to such pipes in the "Natural History of Selborne." Gilbert White, in one of his letters to Thomas Pennant (Letter VI. of the series) describing the forest of Wolmer, refers to tree trunks being found in peat, and dug up by the local cottagers for use as timber. He says that they were often discovered in the winter time by the hoar frost lying longer above them than on the adjacent ground, and he quotes a reference from Hales's "Hæmastatics" as to snow lying longer over drains, etc., "as also where elm pipes lay under ground."—*Journal of the Royal Society of Arts.*

An Unusual Case of Electrical Injury to Street Trees

Some Peculiar Cases Observed at New Haven, Conn.

By George A. Cromie, Supt. of Trees, New Haven

Fig. 1.—A wound made on an elm previous to the change in system. Note how it is healing since the wire was removed.

Fig. 2.—Wounds uncovered at the base of one of the injured elms. The exposed wood is dead, the bark peeling off readily.

It is commonly believed that the effect of electrically charged wires on street trees is of an indirect or mechanical nature. In any city may be found the disfiguring work of the linesman who, if unhindered, ruthlessly hacks away the limbs that interfere with the wires. Abrasions and burns from the live wires weaken branches and afford entrance to decay. Moreover, gas leaks are always more numerous near electric railroads owing to the electrolysis of service pipes near the rails. This is especially the case beneath cross-overs and switches where the salt used to prevent freezing goes into solution and increases the conductivity of the soil.

Living trees possess very high electrical resistance, some experiments made by Dr. G. E. Stone (Fortieth annual report of the Massachusetts Agricultural College) showing 15,000 ohms between electrodes of iron nails driven 10 feet apart into the trunk of an elm 18 inches in diameter. Such resistance allows the passage of so small a current that little injury is done to trees in dry weather, and in all cases the injury is greater during rains when the bark and the ground are saturated with moisture.

Alternating current wires have less effect on trees than those carrying direct current. The injury to a tree in the former case is confined to a small area about the point of contact. The accompanying photograph, Fig. 1, is of a branch burned a third through by a wire carrying 2,300 volts. Upon cutting through the bark a few inches above and below the wound the sapwood is seen to be in a healthy condition, showing that the damage done is strictly local. In time, however, even large limbs are burned completely through and young trees are especially liable to disfigurement where their main branches come in contact with the wires. It is not necessary that the wires be touching the tree all of the time—the frequent contact caused by the wind swaying the branches and wires will accomplish the same result.

The heavy feed wires carrying the direct current for street railways are usually from twenty to thirty feet above the ground where they come in contact with the main branches or upper portions of the trunks of street trees. Leakages frequently escape the attention of employees for considerable time since they do not seriously impair the service. In the case of street lighting using alternating current of high potential the contact of feed wires with branches causes the flickering of arc lights in series. Several such leakages so impair the service that a search is soon made and the trouble remedied.

The arrangement in most overhead trolley systems is to have the wire carry the positive and the rail or ground the negative or return current. In such cases the contact of feed wires with trees causes local or mechanical injury only. Some grounding of current takes place during wet weather and the constant chafing of heavy wires forms a large wound and prevents it from healing. When heavily charged wires are partly worn the resistance develops enough heat to cause local burns.

Late in the spring of 1912 the Street Railway Company of New Haven changed its system, using the rail to carry the positive and the overhead wire the negative or return current. Since the voltage (600 at the station) remained the same and the changes involved affected only the company's plant no notice was given to the city. In June a number of formerly healthy trees commenced to die. Their leaves did not fully develop, turned yellow, wilted and fell from several branches or the entire tree. In every case the injured trees were beside insulated wires furnishing power to the trolley system and an examination showed that both insulation and bark were burned, and that contact was made on the limbs showing the first and greatest signs of damage. Where contact was broken by removing these branches the tree often recovered, but if not the whole tree died within several weeks. On discussing the matter with officials of the Railway Company the reversion of current was mentioned and in a short time all parties were satisfied that this alone was responsible for the damage done to the trees.

Distance from the trolley rail did not seem important, as one tree was killed and several were injured on a street containing wires but no carline. This street ran at right angles to the car line and the injured trees were from 200 to 1,000 feet distant, but ground connection may have been made through several sewer and gas pipes which ran near the trees and into large mains near the rails.

Another immediate effect of this change was the greater insulation required. Many wires having slight or occasional contact with trees formerly showed either no leakage of current or one so slight as not to injure the rubber insulation; they now burned through the insulation and injured the tree. Linesmen who would formerly handle bare live wires from the ground using only a dry leather glove or felt hat now would not touch them without rubber gloves. Where chafing strips of dry wood formerly prevented injury to trees the wooden strip, the tree, the rubber insulation, and strands of the wire itself were burned. Trees in contact with wires were so charged that climbers were unable to work on them in wet weather and anyone standing on the ground and touching them received a distinct shock. Sparks were produced by rubbing the wire back and forth against the tree and anywhere, as a matter of fact, many injured trees were first reported by citizens who noticed these sparks at night.

In all cases of injury the insulation was burned off the wires at the place of contact and no injured trees were found without such direct contact with bare wires.

The first step taken to remedy these conditions was to locate the trees already injured and remove the wires touching them, the next to prevent further injury on all streets having these overhead trolley wires. Two gangs were sent out, each made up of linesmen accustomed to electric wires and city climbers equipped for tree work. Most of the street trees in New Haven are large, but all sizes may be found on one street. They are close together and the parking spaces, or strips between the sidewalk and curb, where both trees and poles must be placed, are very narrow. A relocation of wires causing them to avoid trees was made, dead and badly injured branches were removed and wounds treated, small and unimportant branches touching wires were removed and wooden sleeves were placed on the wire where contact could not be avoided.

The first sleeves were of seasoned wood, sawed in the middle lengthwise and grooves slightly larger than the wire. Hot coal tar was poured into this groove, the two halves were joined together on the wire and the compound when cooled formed a cement that both excluded moisture and kept the sleeve from slipping along the wire. After several rains some of these proved ineffective, small airspaces in the tar admitting enough moisture to start a small leakage of current which grew larger as the tar carbonized. A new type of insulator was then tested and used entirely without any further injury to trees. It consists of two four-inch boards running lengthwise with the wire but separated from it by porcelain cleats at each end and joined together at the two ends with bolts running through the porcelain cleats.

Altogether 51 trees were killed or so badly disfigured as to be of no value, large limbs were removed from 67 which afterwards recovered, while several hundred were saved by removing smaller branches in contact with wires. The Street Railway Company paid for all work done, as well as the expense involved in planting new trees.

An examination one year later showed 9 trees which died the season following injury, but the rest (and half the

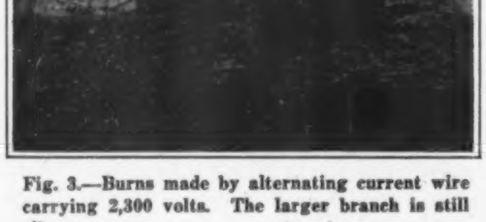


Fig. 3.—Burns made by alternating current wire carrying 2,300 volts. The larger branch is still alive.

Fig. 4.—One of the trees killed. An insulator was put on, but it was too late to prevent injury to the tree.

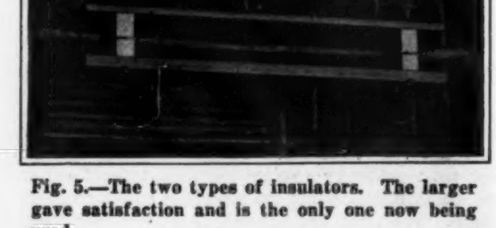


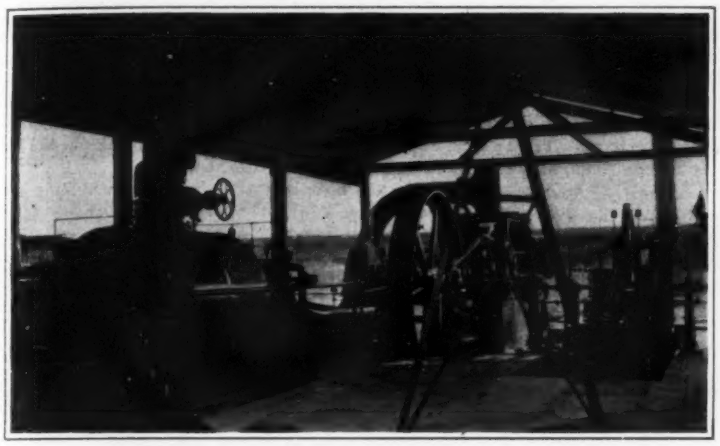
Fig. 5.—The two types of insulators. The larger gave satisfaction and is the only one now being used.

branches had been killed and removed from several) were thriving and new tissue was forming on all wounds. In one living tree a strip of cambium was dead, extending from the injured branch to the roots, but as this branch was large, 16 inches in diameter and only 10 feet above the ground, this would be expected if the branch were removed for other reasons. The trunks of the others were uninjured, but a close examination of the cambium with a hatchet showed dead spots of tissue and peeling bark a few inches below the surface of the ground and usually along depressions in the side of the stump where water channels would naturally form. There were no signs of charring or burned wood.

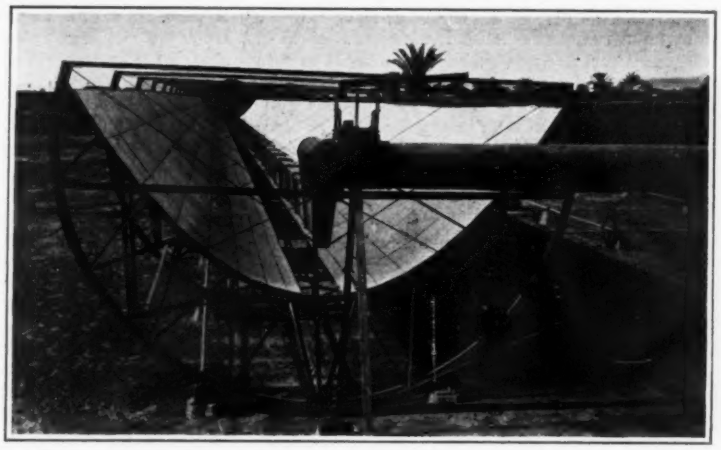
Local electricians have not satisfactorily explained the increased and changed character of the damage to trees since the negative current has traversed the wire. To our knowledge the only previous record of similar damage is by Dr. Stone (see bulletin before mentioned) who claims it "due to a heating of the film of water on the outside of the bark" and further "the bark is thicker at the base and absorbs more moisture and undoubtedly there are more salts in the watery solutions in the bark, and the roots would appear to be much more favorable for the conduction of the current than the dry stems." Although this explains at least part of the damage, no dead tissue or other direct connection could be found between the stump injury and the branch killed and in contact with the wire. Again there was a constant leakage on green trees, as shown by the spark produced in making and breaking the contact even on dry days.

Another possible explanation has been shown in a chemical analysis made at the Yale Forest School, New Haven, which showed traces of copper and zinc in several sections of wood taken from injured trees and at some distance from the place of contact. These two substances are used in manufacturing the insulated wire which, as noted before, was always found partly eaten away, and both are known to have a very toxic and destructive effect on living plant tissues.

One thing can be gained by our experience. Any electric railroad intending to change its system from a positive to a negative overhead wire should first take steps to properly insulate all street trees, and city foresters and tree wardens will certainly save many valuable trees by seeing that this is done.



The low pressure steam engine at the sun-power plant.



The focusing mirrors which concentrate the sun's rays upon the boilers.

Sun-Power Plant

A Comparative Estimate of the Cost of Power from Coal and from Solar Radiation

There are certain steps in the progress of the star which come as unexpected surprises.

Others come in answer to a more or less prolonged search after the solution of a problem clearly recognized as capable of and calling for such solution.

It is among the latter class of technical efforts that we must place the work now in progress in Egypt with a view to establishing there a sun-power plant.

That the plan of utilizing as directly as possible is essentially rational needs no emphasis. The sun's rays stream down upon us uninvited day after day, only to be allowed, for the greater part, to go to waste. What power we do employ in the industries represents only a small portion of this steady stream, a portion which, so far as coal is concerned, has been stored up for us in long past ages at a rate wholly inadequate to renew for us to-day our supply as we consume it. At the present time the direct utilization of the sun's energy is an interesting problem, and one which may bring a very enviable reward to him that solves it. But in the future the problem may become acute, its solution a matter of urgent necessity. True, the problem will probably be solved before this stage is reached, though it is too early to prophesy what method will ultimately be adopted to harness the ethereal sunbeam. Will it be by the use of a low-pressure steam engine? Or will some photochemical process be used? However this may be, the only method which has to-day passed beyond a speculative stage is that of heating water in suitable boilers, heated by the sun's rays, which are concentrated upon the water by reflecting mirrors. We have repeatedly had occasion to refer to the sun-power plant erected in Egypt according to this system. A comparative estimate has recently been prepared to show the relative commercial merits of a coal-steam plant and the Cairo sun-power plant. We reproduce here the essential points of this report:

London, November 8, 1913.

The Sun Power Company, Limited.

Gentlemen:

In accordance with your request I have made careful estimates of the cost of construction and erection at Cairo of your steam generating plant which utilizes the concentrated rays of the sun, and have also compared it with an up-to-date coal-burning steam generating plant of the same capacity. My calculations for the sun-power plant are based upon the results given in the very able report of Messrs. Ackermann & Walrond upon the steam actually generated by your plant in Cairo, which provided all the steam necessary to drive a 50 horse-power engine during ten hours of the day.

I have also compared the cost of running this plant with that of running a modern coal-burning steam generating plant of the same power working under the most economical practical conditions.

"Coal in the inaccessible regions of the tropics costs from $15 to $40 per ton, and in order to reduce the cost of the fuel item to the lowest possible figure, the calculations for the coal-burning plant have here been based on using high-pressure superheated steam generated in a modern water-tube boiler and used in a high class compound condensing engine.

"The Cairo sun heat absorber is a steam producer pure and simple, but generates its steam without the use of coal or any other fuel. The engine used in connection with the sun steam generator will be of a special low-pressure condensing type, and although this type of engine will require a cylinder of larger dimensions than either of the cylinders of a compound condensing engine using high-pressure steam, nevertheless its cost will be sufficiently less to make up for the increased cost of the somewhat larger condenser of the sun-power plant.

"In regard to the question of labor necessary to operate the respective steam generators, the cost in this estimate has been assumed as being the same for either plant.

"The mirrors of the sun-power plant require washing down. This, however, is compensated in the coal-burning plant by the labor needed for stoking and the handling of the coal and ashes, but as the powers of the plants are increased the cost of labor required for the coal-burning plant would go up in greater ratio.

"Basing the cost of manufacturing the 50 horse-power sun steam generator upon its construction being carried out by the use of modern special appliances and tools, it is estimated that it could be manufactured and erected in working order at Cairo for $7,800.

"A coal-burning steam-producing plant of the same capacity of boiler and setting, feed water heater, superheater, foundations, buildings and chimney stack, will cost erected in working order at the same place $3,850.

"The expenses of the respective plants for one year are estimated to be as follows:

SUN-POWER STEAM GENERATOR WORKING 365 DAYS FOR 10 HOURS PER DAY.

Interest on capital expenditure—$7,800 at 5 per cent	$390.00
Wear and tear depreciation at 5 per cent	390.00
Total	$780.00

COAL-BURNING STEAM-GENERATOR PLANT WORKING 365 DAYS FOR 10 HOURS PER DAY.

Interest on capital expended—$3,850 at 5 per cent	$192.50
Wear and tear depreciation at 5 per cent	192.50
Coal consumption at 2 lbs. of coal per brake horse-power hour = 163 tons at 9s. 8 1/3d.	395.00
Total	$780.00

"The above comparison shows that the sun-power steam generator will compete in the tropics with a coal-burning steam generating plant which can obtain its coal at a rate of only $2.40 per ton delivered to the furnace doors.

"Any excess in the cost of coal burning beyond this figure is clear profit in favor of the sun-power plant, but if the cost of coal in those places in the tropics where the sun-power plants will be most useful may be taken at not less than $15 per ton, the saving would be shown as follows:

COST OF WORKING COAL-BURNING STEAM-PRODUCING PLANT AS ABOVE.

Interest and wear and tear depreciation	$385.00	
163 tons coal at $15	2,445.00	
	$2,830.00	
Cost of working sun-power steam-producing plant		$780.00
Saving		$2.050.00

"The above estimate shows that with coal at $15 per ton there is a saving of $2,050 per annum, or nearly 52 per cent on the extra cost ($3,950) of the sun-power plant over that of the coal-consuming plant, which would mean that in less than two years the saving in fuel effected by its use would cover this extra cost and in less than four years the whole of the cost of the sun-power plant would be liquidated, and for every dollar per ton added to the cost of coal above $15 the sun-power plant would save an additional $163 per annum."

An Interest-computing Machine has been invented by a Hungarian, according to a consular report from Budapest. The instrument is said to be comparatively simple and inexpensive. It is about the size of a watch. On setting the hands at the proper positions on the dial, the amount of interest in each case is indicated on the face of the instrument.

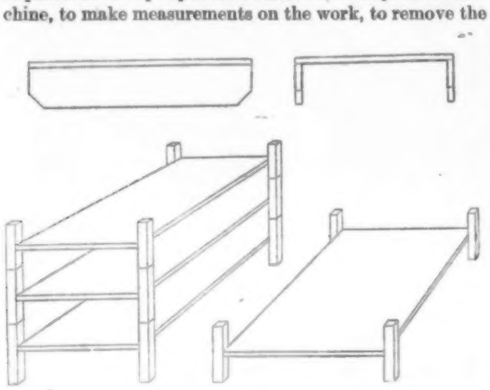
Possible Economies in Shop Transportation*

Reducing Time Lost Between Machine Operations

By Robert Thurston Kent

The adoption of scientific managment has compelled the study in industrial plants of many subjects which heretofore have received but scant attention. When the work of increasing shop efficiency was first taken up, machine operations were the subject of closest scrutiny, and economies that were never dreamed possible were effected in the length of time required for different machine operations. While the possibilities of saving along this line have by no means been exhausted, engineers engaged in management work are now finding it profitable to turn their attention principally to other phases of factory operation.

One of the greatest fields for improvement which made itself evident within the last two years is that of internal transportation. In the study of machine operations, it was early recognized that the handling time was greatly in excess of the actual machining time. That is, the time required to set up a job on a machine, to adjust the machine, to make measurements on the work, to remove the work from the machine, and to clean up after the job, consumed much more time in many cases than, for instance, was consumed in taking two cuts over a given cylindrical surface in a lathe.



Transfer truck platform for assembly groups, showing how they may be nested.

In like manner, it has been discovered that the time lost in picking up material from the floor and lifting it to the work bench or machine, piling, unpiling and repiling in storeroom and shop, and in moving work in process from one point to another, was out of all proportion to the time consumed in the actual manufacturing processes. While this fact has been recognized in a more or less hazy way for a good many years, it is only with the advent of a number of devices intended to effect economies of motion that the problem of cutting down the time and effort required to handle material in the shop has been made the subject of a really serious study.

THE USE OF THE TRANSFER TRUCK

Chief among these devices which have come into prominence in the last few years is the elevating or transfer truck. These have been used for a number of years in the printing trades, but it is only within a comparatively short time that their value in the metal working trades has been recognized. These trucks consist essentially of a four-wheeled frame and a separate platform or top. By means of a suitable lifting mechanism, this platform can be elevated from its normal position a distance of about two inches. In connection with this truck, there is used a platform mounted on skids of such height that the truck, with its platform lowered, will just fit underneath. The material which is to be transferred from one point in the shop to another is piled upon this platform. The truck is then backed underneath it and by means of the lifting mechanism the truck platform is elevated, thereby raising the loaded platform from the floor. The truck can then be moved to any point desired, and a reversal of the operations for lifting will lower the load to the floor, after which the truck can be withdrawn and used elsewhere.

Even with this simple arrangement, the economies effected in transportation and in investment reach startling figures. Contrary to the usual course, the claims made by the manufacturers of these trucks are not extravagant. As a matter of fact, they undershoot the mark. The following is a list of the savings which one manufacturer claims can be effected by these trucks:

Trucking costs	50 per cent.
Storage space	30 per cent.
Time	30 per cent.

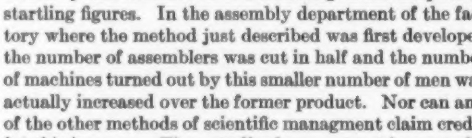
In a recent article on this type of truck the writer presented the following figures as showing the possibilites of economy with the transfer truck: "Take the item of costs. The items to be considered are the first cost of the outfit, the interest on the investment, depreciation, maintenance, and wages. An ordinary truck will cost on the average $10. In a plant requiring 100 trucks this is an investment of $1,000. Interest is $60 per year, and maintenance and depreciation should be figured at not less than 20 per cent., or $200 per year; total, $260. One automatic truck will cost on an average $100, and the platforms and skids for it $1 each. A single truck can take care of 100 platforms, so there is an initial saving of $800. Interest will amount to but $12 per year; maintenance and depreciation at 20 per cent. to $40; a total of $52, or a yearly saving of $202 in favor of the automatic truck. These items alone represent a saving of far more than 50 per cent.

"Now consider the wage item. The man who does the trucking usually loads and unloads the truck. For a haul of 500 feet the time consumed in loading and unloading a truck is easily four times as much as is required to move the load. For shorter hauls, the proportion of time required to load and unload will be greater. But, for convenience, put the figure at four times as long. The truckman will be paid, say $2 per day of 10 hours. Of this, 40 cents will be paid for the actual handling of material, and $1.60 for loading and unloading. With the automatic truck, the time of loading and unloading practically disappears, so that there is a clear saving of $1.60 in every $2 expended. If the moveman is properly routed and kept at work the entire 10 hours he can do five times the work with an automatic truck that he can with one of the ordinary type. Therefore, four men can be displaced, resulting in a corresponding saving in trucking costs."

THE TRANSFER TRUCK IN THE ASSEMBLY DEPARTMENT

Since a systematic study has been made of the possibilities of these transfer trucks, their scope has been widely extended. For instance, in one plant they are being used to transport machines in process of assembly throughout the factory. Neither the machines nor any part of them are allowed to touch the floor once they have been elevated to the working level. This is accomplished by means of a table especially designed to be carried on the transfer truck. This table is so constructed that either one of two sides can be used as the top, thus giving a working surface at two different levels. The transfer truck will fit underneath the table in either one of its two positions. In the shop where this system was developed the castings when they leave the cleaning room of the foundry are placed in appropriate receptacles, which receptacles are supported on these tables in one position or the other. Tables and receptacles are moved from one point to another in the shop by the simple operation of backing the transfer truck underneath the table and carting the whole outfit to the next machine or process.

When the various castings entering into an assembly group have passed through the different machine operations they are assembled on one of these tables, which is at the proper hight to act as a working bench. The various group assemblies can be brought together on these tables and assembled into the completed machine without any lifting or lowering by the worker. The savings effected by this elimination of rehandling in the shop reach startling figures. In the assembly department of the factory where the method just described was first developed the number of assemblers was cut in half and the number of machines turned out by this smaller number of men was actually increased over the former product. Nor can any of the other methods of scientific managment claim credit for this increase. Time studies have not yet been made, nor were tasks set in assembling. The entire saving was due to the total elimination of handling and rehandling by the assemblers.

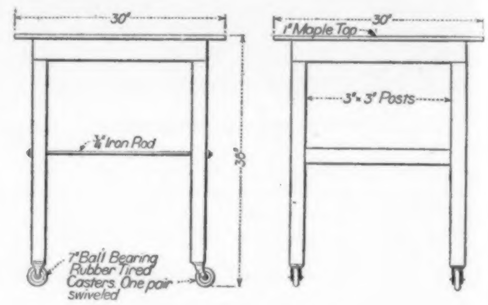


Storeroom rack for transfer truck platforms. The platforms are lifted to place by a portable elevator.

THE TRUCK AND PORTABLE ELEVATOR IN THE STOREROOM

By means of a combination of these trucks and skidded platforms, and of one of the portable elevators which are now available, time and labor in the storeroom may be much reduced. Several of these portable elevators are built so that when the lifting platform is in its lowest position it will just fit underneath the skid platform used in connection with the standard transfer trucks. The older procedure in the storeroom is to bring the raw or finished material from the delivery cart or the machine in the shop which has performed the last operation on similar finished parts to the storeroom in a box or box truck. In the storeroom it must be rehandled from the box to the bins and in the case of many small articles this means the expenditure of considerable time and labor.

Consider now how this feature is taken care of under the new conditions. Material received from outside is piled as it is removed from the delivery wagons, on one of these skidded platforms. A transfer truck picks up the platform and conveys it to the storeroom. It sets it down on the storeroom floor and the portable elevator replaces the truck. The lifting platform is then raised a few inches, and the elevator pushed to the point in the storeroom, where the material is to be stored. Instead of a series of bins of greater or less size, the storeroom comprises a series of racks fitted to receive the skidded platforms. Arriving opposite the rack in which the material is to be stored, the loaded platform is raised by the portable elevator to whatever hight is necessary, and is then pushed into the rack, this operation being facilitated by the rollers which form the surface of the lifting platform of the elevator. In the case of materials which are finished in the shop, and which are to go to the storeroom, the process is essentially the same. Under modern conditions the material, as the last machine operation is completed on it, is piled on one of these platforms. The transfer truck picks it up, moves it to the storeroom, and the operation of placing it in its correct location is the same as before.



A transfer and work table.

It is evident that this method of handling a storeroom results in great economy of space. In an average storeroom fitted with bins, the amount of waste space is enormous, due to bins being but partially filled. In the storeroom fitted with racks and using platforms as above described, every inch of space can be utilized, inasmuch as the various platforms can be subdivided, if necessary. The economies which these devices make possible in storeroom labor are also obvious. Where there is no rehandling of material from tote box to bin and from bin to tote box, the number of men required to take care of a large storeroom can be materially cut down.

REDUCING HANDLING TIME ON MACHINE PART ASSEMBLIES

At an establishment known to the writer an adaptation of the skid platform has been made which enables the transfer truck to effect great economy of space in the assembling department. Instead of the old form of skid platform one has been developed which bears a rough resemblance to a four poster bed. It is shown in one of the accompanying illustrations. These platforms are so constructed that the feet of one may be placed upon the projecting tops of another platform, thus giving a two, three, four or five deck platform, as may be desired. Means have been provided whereby portable sides can be attached to each platform, thereby forming, as it were, a box mounted on posts. The transfer truck can be backed underneath the lowest of these platforms, and the entire set picked up and moved at one operation.

The particular value of this construction lies in the fact that all the parts for one machine can be grouped together and moved at one time and to one location. They can also be grouped in about the relative position they will occupy in the completed machine. For instance, all the parts entering into the base group of the machine can be

*Reproduced from *The Iron Age*.

placed on the lowest platform. On it is superposed another platform on which the parts entering into, say, the frame work of the machine are gathered; on a third platform will be grouped the parts entering into the transmission; while on a fourth may be parts which are to enter into the upper portion of the machine. These packets are all arranged in the storeroom, and when the machine is to be assembled they are moved as one to the assembly floor: the parts which are to be used nearest the ground are on the lower platform, and the parts farthest from the ground are on the upper platform. The assembler has thus to move each piece a minimum distance before it arrives at its final resting place in the machine. The parts all being in one spot, practically speaking, there is no time lost covering more or less horizontal distances, as would be necessary were the different pieces in tote boxes or laid on the floor or on the bench side by side. The saving of time which is possible by this method is obvious, and its amount depends upon the character of the assembly job.

ELIMINATING REHANDLING BETWEEN MACHINE OPERATIONS

The governing idea in all studies for the cutting down of unnecessary movements between machine operations is that the final position of a piece in one operation should be the initial position for it in the next operation, and there must be no rehandling between operations. The transfer trucks above described lend themselves quite well to this arrangement, but there are many cases in which a still better device for the purpose can be utilized. This is a transfer table. The idea, the writer believes, was first developed in a bookbinding establishment. It has been extended, however, and applied to many different industries. The writer has made use of it in a number of cases, although none of them has been in the metal working trades. It is easily possible, however, to adopt it to metal working.

The table used in the bookbinding establishment above referred to was about 36 inches square and 30 inches high. It was strongly built and cross-braced, and was provided with large ball-bearing casters, two of which were swiveled, thus enabling the table to be moved at will in any direction. These tables were used as the feed delivery tables for a number of machines. They were piled with raw material, consisting, say, of a number of signatures of a book which were to be stitched together and moved to the stitching machine. The various book parts were fed from this table into the machine, and as they were received at the delivery side of the machine they were piled on a similar empty table at that point. When the second table was filled it was moved to the next machine operation and became the feed table at this point. The first table at stitching machine, now empty, when the second one was filled was then moved over to the delivery side of the first machine, ready to receive stitched books, the component parts of which were brought to the machine on a new table. The writer has no figures available as to the economies effected in the bookbinding establishment, but, upon adapting the same idea to a paper-box factory, he found that it was possible to increase the output nearly 40 per cent by the use of transfer tables, instead of having the operators pick up and carry the various boxes to and from the different machines. This adoption of the transfer table to the box shop included the instruction of the operator to lay the boxes on the tables as they finished the operation, arranging the work to be most convenient for the operator at the next machine, and this arrangement added materially to the time saved.

Action at a Distance

It is evident that something will soon have to be done to check the congestion of individuals crowding from one part of a city to another and interfering with each other both physically and mentally. In nearly every great city there is an increase continually in transport facilities, followed naturally by an increase in size and population of the commercial and other buildings which are served by those facilities. It is the old story: facilities create traffic, and then traffic demands more facilities, and so the whole system keeps jacking itself up in ratchet fashion and there is no apparent end or relief in sight. Under these circumstances it is evident that we are on the wrong track, and that something else will have to be done if any kind of satisfactory growth and development is to be attained.

The fundamental difficulty in the present system seems to be the idea that it is necessary for individuals to come into close proximity to each other if they are to transact business or to exchange ideas, or make plans under which they are to work in any co-ordinated manner. It is not surprising that such an idea should have become firmly ingrained into the minds of men in past ages, when there was no other means of meeting or exchanging ideas than that of personal contact. With the modern development in mail facilities, in the extension of the telegraph and submarine cable, and especially of the telephone, this idea might seem to be modified, and to a certain extent this has been the case, but at the same time there is a vast amount of running to and fro and increasing knowledge by means which are really crude and primitive when compared with those which are even now at our disposal.

The extent to which it is really unnecessary to see people face to face has been demonstrated by the enormous extent to which the telephone is used both for local and for long-distance conversation. All kinds of business is transacted over the telephone, and without it not one tenth of the present rapid, really high-speed business could be carried on. Nevertheless, we have every day before us the example of crowded trains, both on the surface, in the air, and underground, people crowding, hustling, and jamming together to get to each other, when what they really want is only to get their ideas, phrased in words or arranged in plans without the real necessity of their persons being within reach at all. It is evident, therefore, that if some means of sending thoughts to a distance in such a shape that they could be co-ordinated perhaps by several, instead of by a single conversation at a time, and in connection with such certainty that one could know exactly with whom one was talking, and could receive such intelligent responses as one would expect to get if one were face to face with the speaker, it would be unnecessary for many people to travel to and from their work at all, and all that would be necessary would be for them to be placed in connection or communication with the parties with whom they were to deal and carry out the entire day's work without moving from their homes. This idea relates only to conversation, but there are many things which require to be laid out and examined, such as drawings, plans, correspondence, tabular matter, and things of that sort. These, however, can easily be sent, certainly more easily than the person himself can carry himself with them, if proper facilities were provided. Apparently the most available means for transporting such material nowadays is the pneumatic tube. This is in use between branch post office stations and the main central station, and there is no reason why it might not be so extended as to be as available for everyone as the present lamp post or pillar box for mailing letters is for the collection of mail and its transmission to the other terminus. It may be said that it is desirable to know with whom one is talking or dealing, and that a face to face conversation is in many cases absolutely essential. This may be true, but it does not follow that face to face conversation need mean that the two bodies should be in close physical proximity.

Already methods of transmitting portraits by telegraph have been devised, and it is not at all impossible that before very long, when the telephone call comes, there will appear with it the face of the person who is talking, so that the speaker might be readily identified, not only by the voice, but by the visage of his companion, as accurately as if he were in the same room with him. If, then, the face and the voice and the words and the writing or the plans and drawings can be transmitted far more rapidly and with less difficulty than the physical transport of the individual, the latter would seem to be the primitive and roundabout way of doing things, and the former should soon become considered the normal and legitimate way of transacting business. What this would mean is readily evident. The great crush and crowding back and forth in our great cities between the residence and the business section would be diminished and reduced to a minimum, and most of the difficulties readily avoided, so that the present facilities would be ample for all the transport that would be required under the new system. What we need is not more railway track, nor subways, nor means of transporting human bodies, but far greater facilities for transmitting the intelligence and material, so that a man in charge of many business interests might sit in his study and communicate accurately, rapidly and effectively with them all far more successfully than he could by passing from one office to another, attending one board meeting, another committee meeting and generally endeavoring to convey his own body where he really needs to convey only his own ideas and words and thoughts.

It will be said that one of the principal difficulties in this connection is that of the terminal connection, and this is doubtless so. This was the difficulty which delayed the introduction of the telephone, and it has been truly said that the modern telephone switchboard and exchange was itself as great an invention as the original speaking telephone. It required both of them in order that the proper facilities and advantages of the entire apparatus could be utilized. As a matter of fact, this question of terminal facilities is the principal difficulty in connection with the transport of individuals. There is little or no trouble in transporting people several hundred miles at high speed; the real difficulties appear when the distribution of the individuals at the terminal is attempted, and this is growing worse and worse all the time, because it is still being done after the same primitive fashion as obtained when railroads were first operated. It is practically the same problem in all instances, and as soon as efforts are turned toward the proper utilization of the facilities which are, in the main, already available, just so soon there will appear a relief.

An excellent sample of the way in which such a development has already taken place appears in military matters. Formerly the commander led his troops into action, and his personal example often had much to do with the manner in which the attack was made; to-day he occupies some post of observation, from which he can perceive the entire field or receive reports from many points, and conducts the battle by telephone far more effectively than if he were actually present at the front. The great commanders of business, it is true, conduct their plans from offices which are not always readily accessible, and employ the telegraph, the telephone, and all the mechanism of administration to enable them to command the field of operations. It is only necessary so to extend this method of action at a distance as to permit it to be applied more generally and effectively in ordinary affairs.

Before the telephone came into use, certain large establishments possessed the luxury of a private telegraph wire, with special operators, and the advantages of such means of communication were highly appreciated. With the advent of a complete telephone system, both local and long distance, these facilities have become common, and it is certain that present commercial and manufacturing operations would come to a standstill, at least for a time, if telephonic communication were to be cut off.

The widespread introduction of far greater facilities for immediate and effective communication would act to produce a decentralization and a reduction in necessity for transport congestion which would be most desirable, permitting manufacturing to be conducted in desirable localities, both as regards power generation and with respect to residence advantages for operatives. Many sociological questions would thus settle themselves, the administrative capacity of the direction would be capable of increased efficiency, the operatives would be enabled to lead happier and more healthful lives, and the rapidly accelerating congestion of the large cities would be checked to an extent which would render existing transport facilities abundantly capable of meeting the requirements.—*Cassier's Magazine.*

Roller and Ball Bearings

Lecturing before the Institution of Automobile Engineers, Prof. Goodman dealt with some points in the design of roller and ball bearings.

The lecture, which was illustrated by numerous lantern slides, gave the result of experiments made on various types of both ball and roller bearings under different conditions of load and at various speeds.

One of the most valuable results to which his investigations had led him was the establishment of a formula which gave the maximum working load in pounds to be allowed for any given ball bearing. According to this, the number of balls in the bearing was multiplied by the diameter in inches cubed, this being multiplied by a constant, given as 500,000 for thrust bearings with flat races, and varying, according to the radius of the race, from 1,000,000 to 1,250,000 for thrust bearings with hollow races. The product divided by the diameter of the balls in inches multiplied by the diameter of the ball race multiplied by the revolutions per minute and again multiplied by a constant, in this case 200 for each form of thrust bearing mentioned, gave the permissible load for the bearing in pounds. By a slight modification the formula became applicable to journal bearings.

It was pointed out that roller bearings when subjected to heavy loads invariably showed a very considerable amount of end thrust, however good the workmanship. In the course of his experiments, generally made under excessive loads, the end thrusts amounted to a very serious figure and greatly increased the friction of the bearing.

The lecturer illustrated a form of roller bearing in which the length of the roller was approximately equivalent to the diameter and in which the end thrust was almost absent.—*London Times.*

Prime Numbers

A table recently prepared by D. N. Lehmer gives a complete list of all the prime numbers between 1 and 10,006,721. The total number of primes thus listed is 665,000. The table enables one to tell at a glance the relation between any two given limits.

Third lock masonry. Erecting forms for emptying culverts.

Third lock construction. General view, looking west from mixer plant.

The "Soo" Canal

The World's Busiest Locks

By Harry Chapin Plummer

Grain of the Golden Northwest, iron ore and copper of the Superior region and coal of the Pennsylvania and Ohio fields! For the movement to and fro of this mighty traffic, which, from 1905 to 1912, totaled almost half a billion tons, a second great American canal is in course of construction at Sault Ste. Marie, at the outlet of Lake Superior. The new waterway will be opened early this year. Steamships, sailing vessels and barges will pass through the longest locks in the world.

Already a canal on the American side of "the Soo," with a lock 800 feet long, 100 feet wide and 21 feet deep on its entrance sill, and another on the Canadian side, with a lock 900 feet long, 50 feet wide and 22 feet deep are in constant service during the open season of navigation. But such has been the growth of shipping in both directions through the famous "Soo" that a third and greater passage is imperatively demanded. Hence the new canal. Nor is this all. For work is well under way in the building of the second of two locks of the dimensions of 1,350 feet in length, 80 feet in width and 24½ feet in depth, the first of which is rapidly nearing completion. These will require the ultimate deepening and possible lengthening of the larger of the locks already in operation in the American canal and undoubtedly will call for the corresponding deepening of the channels and, finally, of the chief harbors of the Great Lakes.

Like all great engineering works conducted in the midst of heavy and constant traffic, the construction of the two locks is being attended with manifold difficulties that are really apart from the actual and gigantic task which has confronted the Government in providing safer and more expeditious facilities for the passage of Lake shipping through what is regarded as the busiest canal in all the world. The excavation for the fourth lock, now in progress, instances the exceeding care with which the War Department engineers are obliged to proceed in preparing the foundation for the latest lock and with which, also, they were obliged to proceed in the excavation for the third lock, the masonry of which is well advanced.

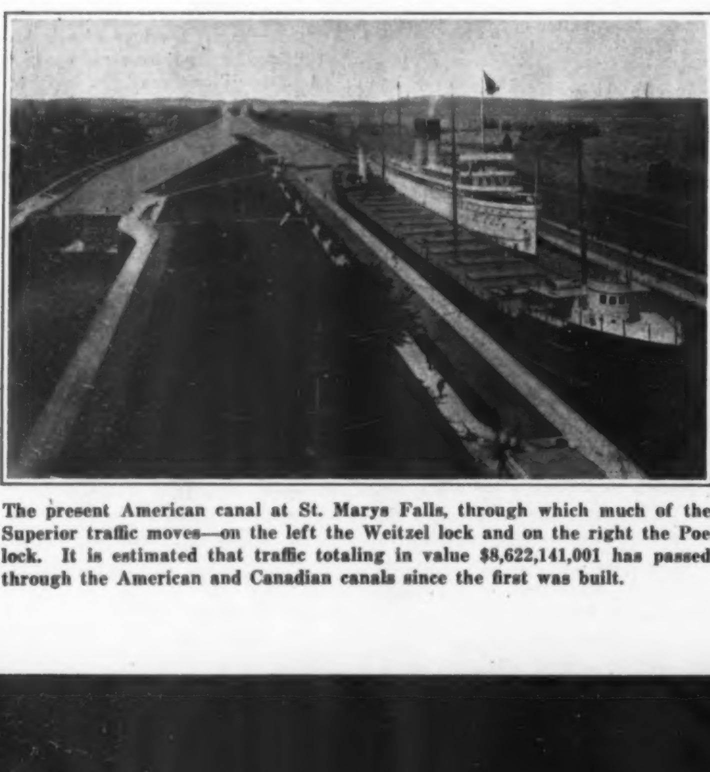
A drama in statistics is the record of traffic which has passed through the portage of the Sault Ste. Marie since Congress, in the '50's, reluctantly granted an inconsequential area of public lands to aid the Commonwealth of Michigan in building the first American canal. From 1855, the year of completion of the canal, until 1864, a total of 1,203,358 tons was recorded, and in the ensuing decade, from 1865 until 1874, 4,829,247 tons, showed a quickening of public use of the waterway. From 1875 until 1884, 14,868,639 tons was the total, while from 1885 until 1894, 80,343,218 tons passed through "the Soo." The decade from 1895 until 1904 registered a traffic of 253,002,697 tons, and in the seven years following, from 1905 to 1912, this was almost doubled, with a total of 441,837,790 tons.

This glance at the development of traffic suffices to show that under normal conditions and with no disturbing factors, "the Soo" presents a scene of undue shipping congestion. It is the last place wherein one would look for excavation and building operations upon a colossal scale. Not only must these in no way interfere with the mighty volume of traffic passing to and fro two score rods to the southward, but the greatest caution must be exercised lest a heavy blasting charge injure the mechanism of the existing locks and bring to a sudden stop the shipping in and out of the greatest of the Great Lakes, with a resulting paralysis of commerce that would be fearful to contemplate. Another reason for infinite care in blasting is the fact that the scene of the excavating is near to a public park which is the playground for the 13,000 inhabitants of the City of Sault Ste. Marie, Mich., and the rendezvous for the crowds of tourists and excursionists from near and far that flock to "the Soo" every year, during the open season. Yet another reason for limited charges of dynamite is the fear of shattering the rock face of the excavation, which is to be left undisturbed.

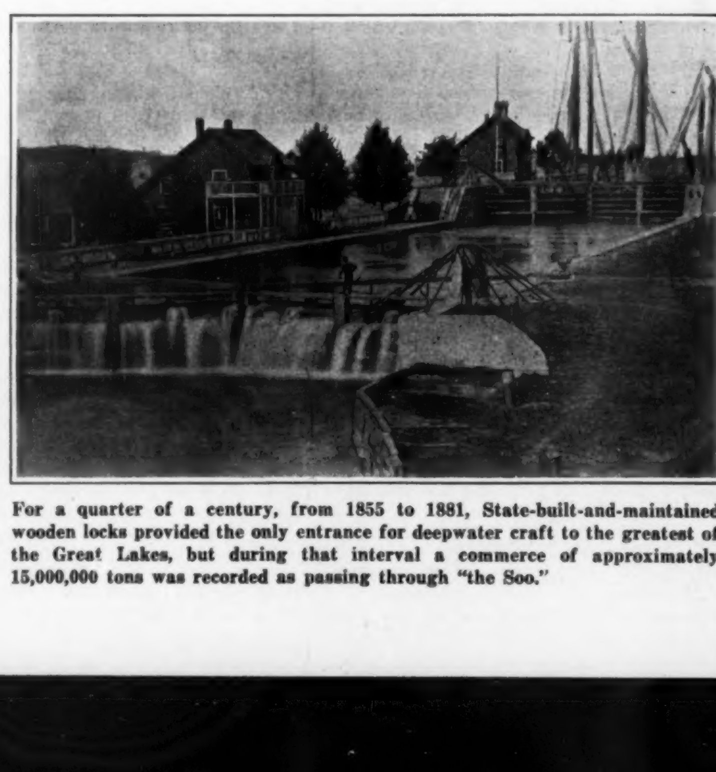
The process that is being resorted to in the excavation for the fourth lock is identical with that followed in the case of the third lock. Advantage has to be taken of a time when not only traffic through the canal is lightest, but when there are the fewest persons in the nearby Canal Park.

Rock channelers strip the rock of earth and vegetable growth, effecting two vertical cuts of 12 and 8 feet, respectively, on either side of the excavation. It is necessary to complete the channeling before any blasting may be done, and so thorough are the precautions taken against accident that the blast holes are stopped at least one foot above the established grade planes within the lock limits and wherever concrete is to be used for future work, and the last yard or so of rock is excavated by hand.

In parallel rows, 35 feet long across the short way of the pit, holes are placed about 4-foot centers in the harder ledges of rock and loaded with 14½ sticks of dynamite and fired electrically by current taken from the electric light wires at 120 or 240 volts. A double system of wiring connects to each of the two caps and the running of several branches from the main feeder lines insures the firing of all charges. Rand and Ingersoll-



The present American canal at St. Marys Falls, through which much of the Superior traffic moves—on the left the Weitzel lock and on the right the Poe lock. It is estimated that traffic totaling in value $8,622,141,001 has passed through the American and Canadian canals since the first was built.



For a quarter of a century, from 1855 to 1881, State-built-and-maintained wooden locks provided the only entrance for deepwater craft to the greatest of the Great Lakes, but during that interval a commerce of approximately 15,000,000 tons was recorded as passing through "the Soo."

Such have been the demands of traffic made upon the existing American and Canadian canals at the outlet of Lake Superior that a second American canal is now in course of construction, to be opened to shipping this year. It will have the two largest locks in the world, measuring 1,350 feet in length, 80 feet in width and 24½ feet at extreme low water.

Great as is the Poe lock of the American canal at Sault Ste. Marie, with its dimensions of 800 feet in length, 100 feet in width and 21 feet in depth at extreme low water, it has come to be superseded by a yet greater lock, or locks. the first of these two is approaching completion; excavation has been started for the other.

Rand air drills are used in two groups, to each of which air is furnished through 3-inch pipes under about 100 pounds pressure. A ten-machine Ingersoll-Rand steam outfit and a sixteen-machine Sullivan electrically-driven compressor each supply a group of drills.

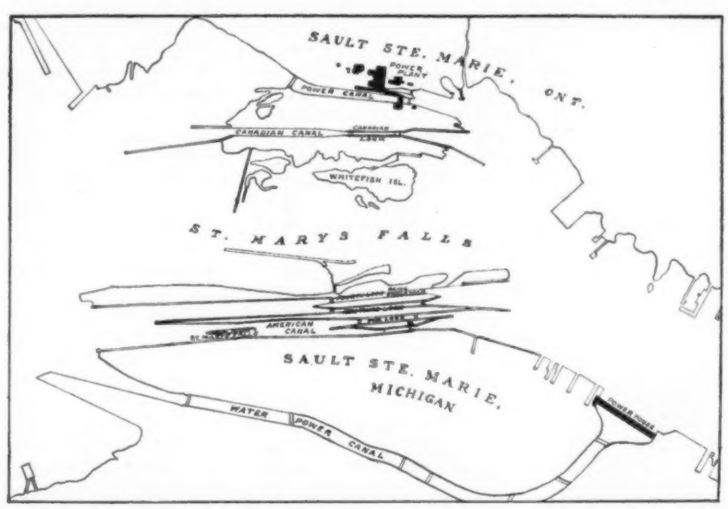
Such is the determination with which work upon both locks is being prosecuted by the Government, under the immediate supervision of L. C. Sabin, Assistant Engineer, U. S. A., that three shifts of men are employed. These enter upon their task at 7 A. M., 3 P. M. and 11 P. M. Illumination for night operations is provided by strings of incandescent lamps hung over the drills and improvised clusters of lights centered about the two shovels.

The severe Northern winter has no terrors for the engineers and their crews, for the masonry work is enclosed by sections, as progress is made, and salamanders used for heating the sand, lime and cement afford warmth for the working forces. As the construction of the fourth lock will be advanced to the masonry stage by next winter, the same system will be followed for operations upon that lock.

Of the concrete gravity type, the walls of both locks rest on a Potsdam sandstone foundation. They are of 50 feet maximum height, with a width at the top of 10 feet and irregular back facing and a bottom width of 26 feet, making an average volume of 1,060 cubic yards per linear foot. Six 9 x 10-foot culverts, 7,000 feet long and separated by 4-foot reinforced concrete partition walls, lie under 2-foot foundation slabs, reinforced transversely with 1-inch rods spaced 5 feet apart, and over the culverts are 7/8-inch bars spaced on 6-inch centers. The culverts are anchored down by two rows of 1½-inch apex bolts, 20 feet long and 4 feet apart. These are let into the rock about 7 feet and extend upward into the partition walls. Supplementary anchors are provided by 1-inch boulder bars, 5 feet apart, on the center line, the tops of the apex bolts being tied together by two 7/8-inch longitudinal bars.

A cable haulage system consisting of two 35-horsepower Stevens haulage machines, each operating ¾-inch steel cables at a speed of 260 feet per minute, effects the transportation of concrete from the mixers and sheds, located downstream from the lower end of the third lock on the St. Marys River, opposite the end of the Poe Lock entrance. There, also, is the crushing plant, which furnishes broken stone and screenings, the stone being obtained from the Bruce limestone quarries on the river, 40 miles away.

The plan of construction of the lock walls is to build



Map of the falls of the St. Marys River, at the outlet to Lake Superior.

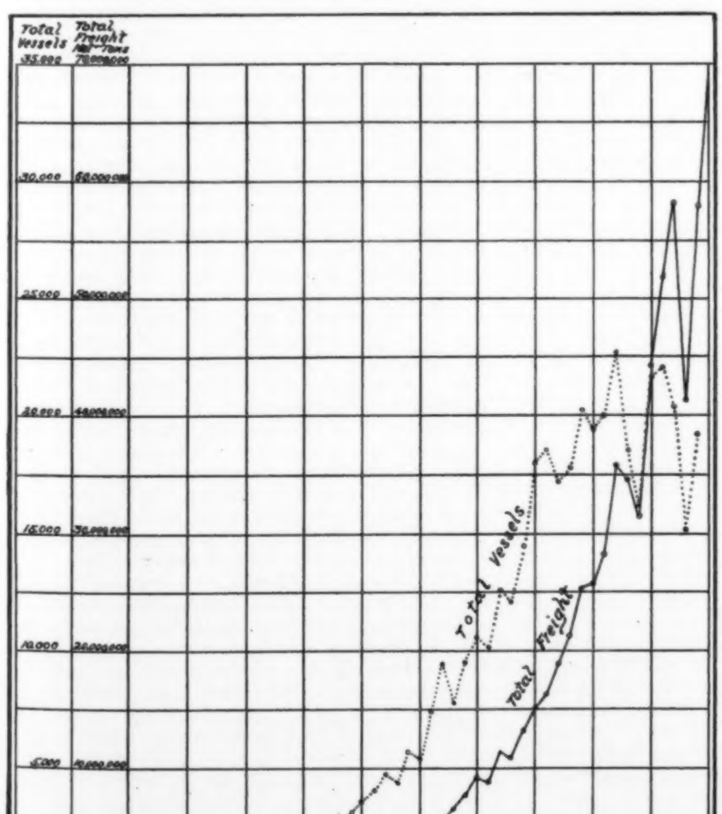


Diagram of the increase in totals of vessels and of cargo tonnages passing through the Sault Ste. Marie canals during the half-century from 1860 to 1910, showing how, by the advances realized in modern Great Lakes ship construction, the number of cargo tonnages leaped ahead of the number of vessels in the last decade.

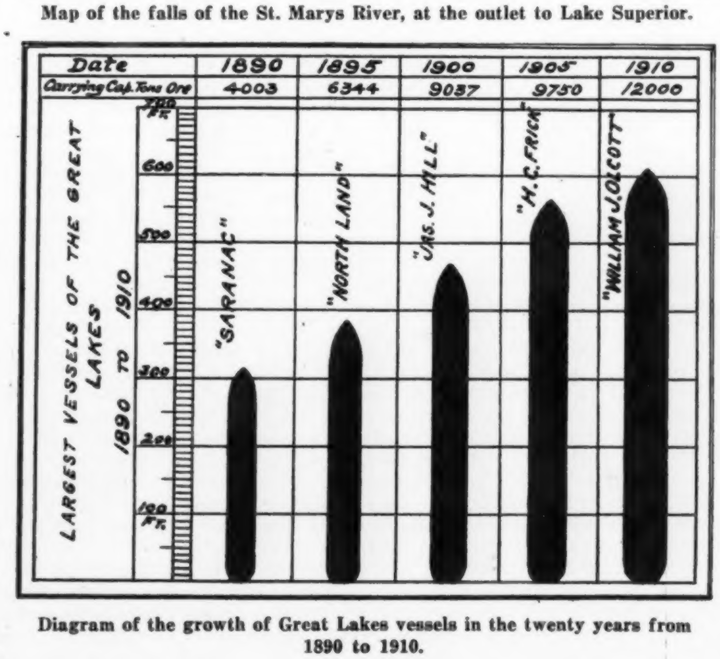


Diagram of the growth of Great Lakes vessels in the twenty years from 1890 to 1910.

away from the mixers, beginning with the steel forms, until one half of each wall is completed. The second crane, with its forms, is then brought back to the center and worked toward the mixer plant while the first continues to the end in the same direction as it started.

For the inner face of the lock walls sheet steel forms in 39-foot lengths are held in place by a mounted structural steel frame made up of 4 angle trusses designed to withstand pressures set up by the successive deposition of 40 cubic yards of concrete per linear foot. Concrete is assumed to exert a hydrostatic pressure for a height of 10 feet and to weigh 100 pounds per cubic foot. For maximum stresses a wind pressure of 20 pounds per square foot in either direction is added to the concrete pressure. Forms for the bulkheads at the ends of the section and the back face are of wood, braced in the customary manner.

The construction of a fourth, as well as a third lock, is the alternative of a plan which was under consideration by the War Department officials before the present work was entered upon, to build only the third lock and to deepen the present Poe lock, the larger of the two already in operation. Assistant Engineer Sabin, than whom none is more familiar with engineering and transportation conditions at "the Soo," argued convincingly against this proposal. He declared that on the Panama Canal the six locks have been built in duplicate merely to provide for accidents and repairs, "where the probable tonnage in sight at present does not exceed one tenth of the present tonnage of the Sault Ste. Marie canals." He observed:

"In determining the relative advisability of building a fourth lock or deepening the Poe lock the difference n the cost of maintenance, as well as the difference in the cost of construction, must be considered. If the Poe lock were deepened no additional force would be required to operate it, but to operate a fourth lock would call for 25 or 30 additional men. If the fourth lock were held as an emergency lock, however, it need not be operated when the emergency did not exist. Another point to be considered is the service that will be given while construction is in progress. If the construction of a fourth lock were begun either before or after the completion of the third lock, an accident to the third lock could not be more serious than a return to the conditions now existing. If, on the other hand, the deepening of the Poe lock were started on the completion of the third lock, the latter would not be able, without serious delays, to handle all the traffic during the year that it would be necessary to close the Poe lock, and a serious accident to the third lock during that year would stop practically all commerce so far as the American canal is concerned. If account is taken of the Canadian lock, however, the importance of this contingency is somewhat modified, but still serious."

To the fact that the existence of the great deposits of high-grade iron ore in the Lake Superior country is supplemented by the cheap transportation of that product, is due the supremacy of the United States among the iron and steel-making countries of the world. The staggering total of 490,539,866 tons has been accomplished by the iron-ore shipments, east-bound, through "the Soo" since the initial traffic of 1,447 net tons in 1855. So the very existence of the steel industry of the United States, concentrated at Pittsburgh, Pa. and Gary, Ind., and at other centers, which annually consumes 30,000,000 tons of iron ore moving eastward and southward through the Great Lakes—and through "the Soo"—is vitally related to the great transportation project. Dependent upon it, also, are the electrical industries, with their tremendous takings of copper, and, likewise, the consuming public of two Hemispheres, who derive their cereals from the common channel of—the Great Lakes. Thus the economic vitality of the American nation, of Canada and of old Europe, are immediately concerned in the improvements at "the Soo."

It is this movement of a vast commerce that would be hazarded by the work of deepening the Poe lock upon the completion of the third lock. Against this Col. W. H. Bixby, the Chief of Engineers, U. S. A., warned in his recommendation of the present improvement, as follows:

"I doubt the advisability of taking any chances of the Poe lock being out of commission for a single season until after the completion of a second deep lock, as in case the Poe lock were out of commission any accident to the first deep lock now under construction would then make the coal and iron ore and grain navigation entirely dependent upon the single existing medium-depth Canadian lock, which is unable by itself to carry the existing traffic."

In the year 1855, 1,441 tons of coal entered Lake Superior, through "the Soo," from the eastern mines, and last year 14,931,594 tons entered.

In the 15 years from 1855 to 1870, little or no wheat moved eastward through the canal, and in the latter year only 49,700 bushels were recorded, but in the year following the wheat traffic amounted to 1,376,705 bushels, and last year it totaled the enormous number of 174,086,456 bushels.

Through the 57 years, from 1855 to 1912, a miscellaneous traffic moved through the canal as follows: 1,797,994 passengers, 29,871,692 tons of general merchandise, 3,067,435 tons of copper, 6,926,423 tons of manufactured and pig iron and 10,930,749 barrels of salt.

It was 12 years or more before Fort Sumpter was fired upon that the bill to grant the public lands for the commencement of the work of construction of "the Soo" canal was before the Senate, and no less distinguished a Solon than Henry Clay arrayed himself among the opponents of the measure. As illogical as non-grammatical was his denouncement of the measure. Said he:

"It is a scheme to squander the public resources upon a chimera beyond the remotest bounds of settlement, if not in the moon!"

Pressure Rises in Electrical Circuits and Apparatus*

Failures of insulation and apparatus consequent on unexpected and more or less unexplained rises of pressure were for many years a concomitant of commercial electrical practice. Nowadays, however, trouble of this kind is relatively infrequent, and in general it may be said that the causes of such pressure rises are well understood. None the less, a proper consideration of the matter demands a fair amount of mathematics, and it may be doubted if the average electrical engineer is as much at home with the subject as he would like to be. If we interpret his position correctly, he must find much to interest him in the able review of the whole matter contained in Mr. Duddell's address with which the present session of the Institution of Electrical Engineers was opened. The address was not in general concerned with new material. Its purpose was to give in a small compass a connected account of work and investigations the official records of which are spread over the technical publications of half a dozen countries.

Although we have suggested that trouble due to pressure rises is of less frequent occurrence at the present time than in the past, it must not be supposed that the subject is not still of great practical importance. So far is it from being unimportant that Mr. Duddell's address is likely to become a sort of standard reference in the future for engineers who may have to deal in practice with the subject of which it treats. In giving a brief account of the ground covered by Mr. Duddell, we regret that we cannot do more than mention the striking series of experiments with which he so skillfully illustrated his subject. We can but remind our readers that as an experimentalist Mr. Duddell has few equals, and state that his display on the occasion here reported was worthy of his reputation.

The causes of pressure rise in cables and apparatus were divided by Mr. Duddell into three main classes—viz., resonance, switching, and arcs and sparks. In respect to the first of these, it is well known that a circuit which contains self-induction and capacity has a free period of its own, and that electric oscillations may be produced in it provided the resistance does not exceed a certain limit. If now an alternator, the period of which is the same as the period of the circuit, is connected to the circuit, very violent oscillations may be set up, with the production of large pressure rises. This effect is known as resonance. The case of resonance which most generally occurs in practice is when a long unloaded cable is connected to an alternator. The necessary capacity for the circuit is furnished by the cable, and the necessary self-induction by the alternator itself. Resonance in such a case as this, owing to the coinciding of the fundamental period of the alternator with the free period of the circuit, does not in general occur in practice. Mr. Duddell quoted only one such case. Resonance of the third, fifth or seventh harmonic of the alternator is, however, not uncommon, although much less frequent with modern than early alternators, owing to the better wave-form of the later machines. Some examples of resonance were quoted by Mr. Duddell. With an old type 400 kw. 2,000-volt alternator, working through a 3 to 1 transformer, resonance with the third harmonic gave a maximum voltage reading of 10,140, or 1.60 times the R.M.S. value, while resonance of the thirteenth harmonic on a 500 kw. 6,600-volt machine of modern type gave a maximum voltage of 14,000, or 2.33 times the R.M.S. value.

Apart from cases of resonance at the normal period of an alternator, the state may arise owing to alteration in speed of the machine, with a consequent alteration in the periodicity. This may cause serious pressure rises if an alternator is run up when excited and connected to a cable system. The same sort of thing may occur if a cable feeding a running motor, or converter, in a substation is switched off at the generating station. The motor or converter will, of course, begin to slow down, and there is risk of resonance occurring at some point. Mr. Duddell suggested that the risk was serious and that the self-induction of the machine might be high enough to cause resonance of the fundamental. He quoted a case in which the switching off of a feeder supplying two motor generators in a substation caused resonance of the thirteenth harmonic and a voltage peak of 16,200, the bus-bar pressure being 6,420 volts. Resonance in the type of cases we have been dealing with only occurs when the cable system is on open circuit, but the same sort of thing can occur on a high-tension system containing a number of step-down transformers, if the secondaries are open circuited. Another possible case would be a step-down transformer supplied through a fairly long cable from a generating station and switched out at the generating station, but left connected on the low-tension side. If this side were alive from the low-tension system in some way, the transformer might transform up with the appearance of resonance on the high-tension side.

Switching, the second case considered by Mr. Duddell, may cause pressure rises quite independently from any arcing or sparking at switch contacts. The best known case is probably the breaking of an induction circuit, such as the field of a generator. In such cases the voltages reached may be very high if the current is suppressed quickly enough, because the whole of the energy stored in the self-induction is set free, and must either be dissipated or stored in some available condenser. A second case of pressure rise owing to switching occurs when an uncharged condenser is suddenly switched on to a generator. In the general case the potential difference between the terminals of the condenser will rise not only to that of the generator, but will overshoot the mark, and may, if there are no losses, reach twice the value. Two examples of this type of pressure rise were quoted by Mr. Duddell. The first concerned 3 miles of cable on open circuit switched on to a 1,000 kw. 5,600-volt generator. The peak rose to 14,500 volts, or 2.6 times the R.M.S. value. The second case was of 2 miles of cable switched on to a 5,000-volt generator of old type. The potential difference rose to 11,000 volts, or 2.2 times the R.M.S. value.

Normally no rise takes place when a condenser is switched off, but if vibration or sparking takes place at the contacts, pressure rises may occur, since after the circuit has been first broken, it will be made again owing to the sparking. This may cause a pressure rise equal to twice the applied voltage, as before mentioned. This effect may be repeated with a series of sparks, and in the worst case it is possible to get a pressure rise of 4.2 times the R.M.S. voltage. Mr. Duddell stated that, in practice, when cables were switched in and out on open circuit, if no sparking took place the peak rarely exceeded the R.M.S. voltage. With sparking the rises might be serious, but with switches in good condition he thought a peak of three times the R.M.S. voltage might safely be considered as the limit. The next case of pressure rise due to switching is concerned with the switching in and out of circuits containing both induction and capacity. Pressure rises may occur in such cases if the resistance is low enough. When the capacity and self-induction are not distributed, the voltage rise may be determined by comparatively simple calculation, but the general case of a circuit with distributed induction and capacity demands advanced mathematics for its solution. From the point of view of pressure rises Mr. Duddell stated that for practical purposes power supply cables could be looked upon as approximating to the limiting cases either of very long or very short cables. This much simplifies their consideration.

If an infinitely long cable be suddenly connected to an alternating-current generator at the moment when the potential difference is zero, as the potential difference increases a current will flow into the condenser, formed by the cable and the earth. The charge will travel along the cable with a certain velocity, and, owing to the resistance and capacity of the cable, the quantity of electricity will gradually become less as it travels along. It will form a wave of gradually decreasing amplitude. As the wave travels along, the phase of the current wave, applied to the end of the cable, continually alters, owing to the revolving of the alternator. Consequently,

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the phase difference between the alternator wave and the current wave traveling down the cable increases progressively. The net result is that in a very long cable the wave traveling along the cable continually diminishes in amplitude, and lags behind the generator in phase. If the cable is electrically very short, however, there will be practically no diminution in amplitude or change of phase while the wave progresses along it, and questions of pressure rise may be solved by treating the problem as one involving localized self-induction and capacity. This is practically the case for all the power lines and underground cables in this country.

For very long lines, such as those used outside of the British Isles, however, the matter is not so simple. If a long line is open-circuited at the far end, the current wave when it reaches that end will be reflected, and its voltage will be doubled. It will then travel back through the generator, to earth, and again be reflected with reversal of phase, but with no increase of amplitude. It will then travel again to the far end of the cable, and again be reflected, and doubled in voltage. This state of affairs will go on until a steady state is built up, and a high voltage may be reached at the far end of the cable. This effect of the building up of the potential at the far end of a line on open circuit is known as the Ferranti effect. The rate of propagation of such a wave along ordinary cables is about one quarter the velocity of light. The effect is very marked with the high frequencies of wireless telegraphy, and is made use of. It is seldom observed on the comparatively short power cables used in this country. We have no space to deal further with this matter at present, but before going on to cases of pressure rise due to arcs, should mention a further case of pressure rise due to switching, which was mentioned by Mr. Duddell. This is the well-known unequal division of pressure over the parts of an induction winding when first switched on. This effect in the past led to the breakdown of the end windings of many high-voltage motor windings and transformers. The effect is due to the potential difference being initially localized at the first few turns, owing to the lagging caused by the condenser action of the remaining turns.

Pressure rises due to arcs and sparks are, in many cases, to be explained by the property of facilitating, or causing, rapid changes of current which such arcs and sparks possess. This property arises mainly from the fact that an arc is generally essentially unstable. That is to say, if the current through an arc increases, the potential difference between its terminals decreases, producing a further tendency for the current to increase. When arcs are used for practical purposes this tendency is controlled by some such means as a steadying resistance, but it is naturally uncontrolled as far as accidental arcs are concerned. An arc in a current containing self-induction thus obviously tends to produce pressure rises in virtue of its instability. The instability of an arc is greatly increased if the electrodes are kept cool, which may occur if they are of metal and are of considerable mass. This effect is further increased if the electrodes are close together, so that they tend to cool the vapor column of the arc. A transverse magnetic field also tends to make an arc more unstable, while shunting it with a condenser greatly increases the instability. The effect of a condenser follows from the fact that if the current through the arc decreases for any reason, the potential difference across it will increase. This will tend to cause the current to flow into the condenser, still further reducing the current through the arc.

The pressure rises produced by an arc or spark are used practically in wireless telegraphy, where the arc is shunted by a condenser. In the most usual arrangement the circuit is supplied with alternating current, the condenser charging up and discharging at each half wave or oftener. Oscillations can, however, be produced by continuous current if the arc is such that $\frac{\delta V}{\delta I}$ is a negative quantity, where δV is a change in voltage produced by a small change of current δI through the arc. The quantity $\frac{\delta V}{\delta I}$ is not in general, however, negative for large-current arcs in air. Large-current arcs in gas and magnetic fields can, however, produce powerful oscillations. With a spark-gap shunted by a condenser, intermittent discharges may take place with either alternating or continuous current, and give rise to oscillations. This follows since the generator may take an appreciable time to charge up the condenser, so that after discharge, which may be oscillatory, a definite time must elapse before the condenser can discharge again. This will result in a regular succession of discharges.

Pressure rises on cable systems may occur owing to arcs at switch contacts or at faults. The effect of intermittent contact when switching cables on or off has already been mentioned, while the pressure which takes place when an induction circuit, carrying a continuous current, is broken is well known. Mr. Duddell, however, pointed out that this latter effect may also occur when an alternating current is broken by an oil switch, and quoted an example in which on a 2,500-volt circuit a rise to 11,000 volts was found. The effect of a condenser shunting an arc was illustrated by a 150 kw. transformer switched on and off to a 2,500-volt main by an oil switch. The worst peak found was 5,500 volts. The connections between the switch and transformer were very short, but on introducing a connection of 60 yards of cable between them, the peak rose to 7,500 volts. In this case the capacity of the cable to earth in series with the capacity of the supply main to earth formed two condensers shunting the arc. Mr. Duddell also quoted pressure rises due to the blowing of fuses, and pointed out that in such cases the arc is nearly always shunted by the capacity of the cables. A fuse blown on short circuit on to the end of a feeder connected to a 2,000-volt 400 kw. generator resulted in a pressure rise to 4,200 volts. Again, the sudden connection of a fuse as a short circuit to the secondary of a 10,000-volt transformer caused a 27,000 volt pressure rise.

The Bursting of Flywheels*

FLYWHEELS may burst from any one of a number of different causes, but the commonest cause is undoubtedly the speeding up of the wheel, owing to the failure of the governing apparatus. If the governing apparatus should become inoperative while the load still remained on the engine, it might happen that the wheel would run away, or that it would slow down and perhaps even come to a stop.

If the accident should consist in the destruction of the governor and the simultaneous throwing off of the entire load (by the breakage of the main driving belt or otherwise), and if at the same time the independent speed-limiting device should fail to operate, then the entire power of the engine might be expended in making the wheel go faster and faster, until it was destroyed by bursting, or until the attendant could shut off the steam supply. Under these circumstances it becomes highly desirable to know how much time the attendant would be likely to have, to do something toward checking the racing of the engine, between the time when the accident occurred and the probable moment of the bursting of the wheel; and to answer this question we have to find out how long it would take the engine, when putting its full power into the acceleration of the wheel, to speed it up to bursting.

We shall take it for granted that the flywheel is made of cast iron, having a tensile strength of 18,000 pounds per square inch. Some cast iron has a greater ultimate strength than this, but castings are notably variable in tensile strength, and some authorities maintain that it is not safe to assume a strength in excess of 10,000 pounds per square inch for the material used in cast-iron flywheels. We are not here concerned, however, with the *safe* strength that can be allowed, because in deciding this point we of course endeavor to err always on the safe side. We wish, in the present case, to make as good an estimate as we can of the stress upon the wheel at the time when it actually bursts.

It can be shown very easily, by the ordinary rule for finding the strain in a flywheel rim, that a solid wheel made of cast iron of the strength here assumed will be on the point of bursting when it attains a peripheral speed of 25,861 feet per minute.

It is well known that wheels with jointed rims are weaker than those with solid rims. This follows from theory, and the fact is also plainly evident in Benjamin's experiments. As a result of these experiments it has become customary, in flywheel calculations, to take it for granted that the ordinary flanged wheel has a strength of only 25 per cent of that of a similar solid wheel, and that the strength of a wheel with link joints in the rim is 60 per cent of that of a solid wheel, and that the strength of a wheel having pad joints in the rim is 50 per cent of that of a solid wheel. We shall assume these figures in our calculation. It should be noted, however, that these factors or "efficiencies" relate to the strain in the rim, and not to the velocity of the wheel. This is a highly important point to understand, because the strain in the rim varies as the *square* of the velocity. A flanged wheel, for example, which has a strength equal to *one quarter* of that of a similar solid wheel, will burst when its speed is *one half* of that at which a similar solid wheel would burst.

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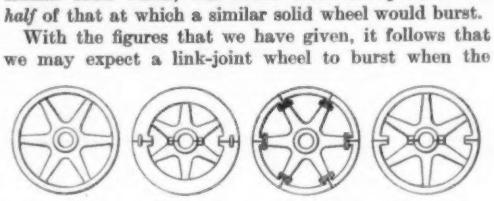
With the figures that we have given, it follows that we may expect a link-joint wheel to burst when the



Illustrating the types of flywheel here considered.

linear speed of the rim is 20,032 feet per minute, a pad-joint wheel when the linear speed is 18,286 feet per minute, and a flanged-joint wheel when the linear speed is 12,930 feet per minute.

There is quite a range of weight in the wheels of steam engines, even when this weight is compared with the horse-power of the engine. In designing the wheel, the weight is chosen with due reference not only to the speed and safety of the wheel, but also to the nature of the work that the engine is to do. To avoid going into this question at all minutely, we have adopted ranges of weight that are suggested by the well-known formula of Rites, assuming that the constant in that formula may vary from 5,000,000,000 to 10,000,000,000 in double-acting engines.

We are furthermore assuming that the normal speed of the rim of a solid wheel, in the regular operation of the engine, is 6,000 feet per minute, and that the normal speed for wheels of other types is lower than this, in conformity with the respective strength-efficiencies as given above for sectional wheels whose parts are joined together by links, pads, or flanges. This is the same thing as taking the limiting working speed, in feet per minute, as 4,647 for link-joint wheels, 4,242 for pad-joint wheels, and 3,000 for flanged wheels.

To find the time that would be required in order to allow an engine to increase the velocity of its flywheel from the normal working speed given in the preceding paragraph, up to the point at which the flywheel would burst, we first divide the weight of the flywheel, in pounds, by the actual horse-power of the engine. If we call the quotient the "weight of the flywheel per horse-power," we then have the following:

Rule:—Subtract the square of the normal speed of the rim of the wheel, in feet per minute, from the square of the speed (similarly expressed) at which the wheel would burst. Then multiply the difference by the "weight of the flywheel per horse-power," in pounds, and divide the product by 127,500,000. The quotient thus obtained is the time, in seconds, that would be required to raise the speed of the flywheel from its normal value generally up to the bursting point.

In applying this rule we should use, as the horse-power of the engine, the power that is actually developed while the engine is running away. This depends, of course, upon the unknown position of the cut-off; and hence it is safest to rate the engine according to the maximum power that it can develop, with the cut-off as long as possible.

The accompanying table gives the results that are obtained by applying this rule to wheels of various kinds, and having a wide range of weight per horse-power. In each case the figures give the number of seconds that would be required to speed the wheel up to the bursting point, starting from the limiting safe speeds that are given above for the respective kinds of wheels, and assuming that the entire engine power is expended in making the wheel go faster.

It will be noticed that the time is quite short in the case of a flanged-joint flywheel with but little weight per horse-power. For example, a flanged-joint wheel that weighs only 5 pounds per actual horse-power of the engine, may be expected to burst in six seconds. This gives the engineer very little leeway indeed, to accomplish anything in the way of making the engine safe. On the other hand, it will be seen that a link-joint wheel that weighs 40 pounds per actual horse-power would probably last for 119 seconds, or practically two minutes, and in this case the attendant would have a fair chance of controlling the engine by hand, by closing the steam valve or otherwise.

The table clearly shows the advantage, from the safety standpoint, of avoiding the flanged joint, and fastening the parts of the wheel together either by links, or by pads at the ends of the spokes. It also shows the advantage, from the same point of view, of making the wheel heavy. In these respects, at all events, the table is in accord with experience, which indicates that it is the light, flanged-joint wheels that usually burst, and that the flywheels of rolling-mill engines, which are usually provided with link fastenings and made very heavy, explode with far less frequency, although they are subject to extremely severe usage.

SECONDS REQUIRED TO SPEED A FLYWHEEL UP TO BURSTING.

Weight of flywheel per horsepower. (Pounds)	Solid wheel	Link-joint wheel	Pad-joint wheel	Flange-joint wheel
5	25	15	12	6
10	50	30	25	12
15	74	45	37	19
20	99	60	50	25
25	124	74	62	31
30	149	89	74	37
35	174	104	87	43
40	199	119	99	50
45	223	134	112	56
50	248	149	124	62
55	273	164	136	68
60	298	179	149	74

Baking Bread*

The Influence of Bran-Extracts on the Baking Qualities of Flour

By H. L. White

It is generally recognized that bran and shorts contain valuable food constituents such as fat, carbo-hydrates other than cellulose, mineral matter and some nitrogenous material. Attempts have been made to improve the bread-making qualities of a flour, by introducing into the flour extracts of bran made with various solvents. Thus cold water extracts and hot water extracts have been mixed with flour in varying proportions with beneficial results. A process has been patented for treating bran in order to recover the mineral constituents for admixture with flour. The bran is treated with water to extract soluble salts and the residue treated with an acid solvent and water and subsequently with an alkaline solution. The acid and alkali solutions are neutralized, and the whole of the extracts are evaporated to dryness, and the residue is reduced to a powder.

In connection with some experimental work on the mineral content of flour, it was found advisable to determine the effect of a dilute hydrochloric acid-extract of bran on the baking qualities of flour made from several varieties of wheat. It has been claimed that an 0.2 per cent HCl extract of bran contains phytin from which an acid identical with Posternak's anhydro-oxymethylen diphosphoric acid is obtained. That phytin is obtained in this manner is denied by Anderson who claims that the extract thus obtained does not correspond in composition with salts of the true phytic acid. Without entering into the discussion of this point, the fact remains that the dilute acid extract contains, in addition to other constituents, both organic and inorganic phosphorous compounds.

EXPERIMENTAL.

The acid-extract used in these experiments was prepared by soaking bran in 0.2 per cent HCl for 16 hours. The proportions used were, bran 300 grammes, acid 1,800 cubic centimeters. The liquid was first filtered through cheese-cloth and then through paper, a clear liquid of a brown color being thus obtained. Analysis of this clear liquid gave the following results:

TABLE I.—COMPOSITION OF ACID-EXTRACT OF BRAN.

Total Solids Grams per 100 C.C.	Ash Grams per 100 C.C.	Total P_2O_5 Grams per 100 C.C.	Inorganic P_2O_5 Grams per 100 C.C.	Organic P_2O_5 (by diff.) Grams per 100 C.C.	Acidity C.C. $N/20$ NaOH per 10 C.C. ext.
3.584	0.917	0.464	0.200	0.264	13.6

In one series of baking tests the acid-extract was neutralized with 0.1 N NaOH, using phenolphthalein as an indicator. In another series a water-extract (bran 300 grammes, water 1,800 cubic centimeters) was used, and in still another, 0.2 per cent HCl was used in place of a bran extract. A comparison of these various extracts is afforded in the following table:

TABLE II.—COMPOSITION OF VARIOUS EXTRACTS USED IN BAKING TESTS.

	Total Solids Grams per 100 C.C.	Ash Grams per 100 C.C.	Total P_2O_5 Grams per 100 C.C.	Inorganic P_2O_5 Grams per 100 C.C.	Organic P_2O_5 (by diff.) Grams per 100 C.C.	Acidity C.C. $N/20$ NaOH for 10 C.C. ext.
Acid-extract	3.584	0.917	0.464	0.200	0.264	13.6
Water-extract	2.776	0.444	0.163	0.110	0.053	3.0
Acid-extract, neutralized	3.785	1.145	....	....	....	....
0.2% HCl	....	....	....	....	....	10 65

BAKING TESTS.

Several series of baking tests were made, some months apart, using flour made from the same samples of wheat but freshly ground for each series of tests. In Series I (spring of 1912) varying amounts of extract were used, while in Series II (fall of 1912) the same amount (150 cubic centimeters) was used in every case. The bread was made in the usual way, the extracts being used instead of water to make the dough. Straight flours from each of three varieties of wheat were used in these experiments: Bluestem (Lab. No. 568), Durum (Lab. No. 481), and Velvet Chaff (Lab. No. 993).

TABLE III.—RESULTS OF BAKING TESTS—SERIES I.—BLUESTEM WHEAT.

1st Baking	Extract C.C.	Water C.C.	Volume Loaf C.C.	Color	Texture
568*A* (check)	...	201	2,460	95	96
568*B*	80	123	2,760	97	98
568*C*	150	52	2,820	100	100
568*D*	150	50	3,020	100	100
2nd Baking			Acid-Extract		
568*A* (check)	...	200	2,460	95	96
568*E*	80	120	2,850	97	98
568*F*	170	30	2,920	98	100
3rd Baking			Acid-Extract Neutralized ("Soapy")		
568*A* (check)	...	196	2,640	...	...
568*G*	80	122	2,590	...	...
568*H*	170	36	2,280	...	...
4th Baking			Dilute Hydrochloric Acid (0.2 per cent)		
568*A* (check)	...	205	2,690	99	98
568*I*	80	121	2,680	101	98
568*J*	140	65	2,700	99	97

* Reproduced from the *Journal of Industrial and Engineering Chemistry*.

In both the first and second bakings using acid-extract there was an increase in volume, amounting to 18 per cent, and an improvement in both color and texture.

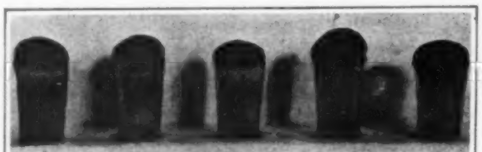


Fig. 1.—1. Check loaf. 2. Water-extract. 3. Acid-extract, neutralized. 4. Acid-extract. 5. Acid alone.

With the neutralized acid-extract there was a decrease in loaf volume amounting to 13 per cent.

In order to determine if the use of acid-extract resulted in an increase of acid-reacting material in the bread, the soft portions of loaves, Nos. 568*A* (check) and 568*D* (150 cubic centimeters extract) were extracted with water and the filtered solution titrated with 0.05 normal NaOH, with the following results:

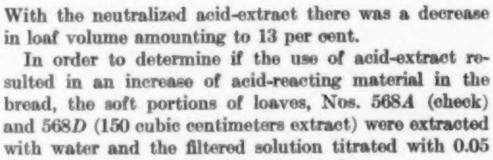


Fig. 2.—1. Check loaf. 2. Water-extract. 3. Acid-extract. 4. Acid-extract, neutralized. 5. Acid alone.

TABLE IV.—ACIDITY OF INNER PORTIONS OF LOAVES OF BREAD.

Lab. No.	$N/20$ NaOH C.C.	Acid-Extract Calculated as Lactic Acid Per cent	Calculated as HCl Per cent
568*A* (check)	4.3	0.193	0.078
568*D* (extract)	8.35	0.373	0.152

The average acidity of the inner portion of 21 samples of fresh bread was found[1] to be equivalent on a dry

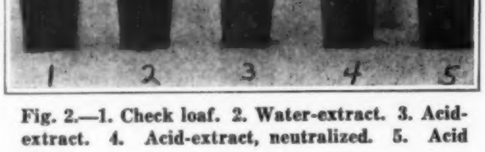


Fig. 3.—1. Check loaf. 2. Water-extract. 3. Acid-extract. 4. Acid-extract, neutralized. 5. Acid alone.

basis to a 0.289 per cent lactic acid or 0.215 per cent hydrochloric acid. Therefore, the acidity of the water-soluble portions of 568*A* and 568*D* is about the same as the average of home-made bread and of bakers' bread.

TABLE V.—SERIES I—DURUM WHEAT.

Acid-Extract

1st Baking	Extract C.C.	Water C.C.	Volume Loaf C.C.	Color	Texture
481*A* (check)	...	190	2,040	97	94
481*B*	80	107	2,090	97	95
481*C*	140	51	2,170	97	96

This flour did not respond to treatment with acid-extract, as the gain in loaf volume was only 5 per cent, color and texture remaining about the same in each loaf.

TABLE VI.—SERIES I—VELVET CHAFF WHEAT.

1st Baking	Extract C.C.	Water C.C.	Volume Loaf C.C.	Color	Texture
			Acid-Extract		
993*A* (check)	...	190	1,980	96	92
993*B*	80	110	2,260	99	96
993*C*	160	30	2,400	98	96
2nd Baking			Acid-Extract		
993*A* (check)	...	187	2,090	96	95
993*D*	80	108	2,340	97	98
993*E*	150	38	2,380	98	98
3rd Baking			Acid-Extract, Neutralized		
993*A* (check)	...	190	2,200	100	93
993*F*	80	113	2,090	99	92
993*G*	140	55	1,970	99	90
4th Baking			Dilute Hydrochloric Acid (0.2 per cent)		
993*A* (check)	...	187	2,090	96	95
993*H*	80	108	2,230	97	95
993*I*	150	38	1,910	94	85

[1] Congdon, Twenty-second Annual Report, North Dakota Agricultural Experiment Station, 1911, Part II.

As shown in the above table there was an increase in the loaf volume of from 13 per cent to 21 per cent when acid-extract was used, and both color and texture were improved. With neutralized extract there was a decrease in loaf volume. With dilute acid alone there was a decrease of 9 per cent in loaf volume, a slight change in color, and a poor texture.

After a study of these results, it was decided to make a second series of baking tests, including in each baking all of the extracts which had been used in the several bakings of Series I and in addition a filtered cold-water-extract of bran.

TABLE VII.—SERIES II—BLUESTEM WHEAT—NO. 568.

Flour No. 568	Extract C.C.	Water C.C.	Volume Loaf C.C.	Color	Texture
Check	...	190	2,490	94	97
Check	...	189	2,480	95	97
Acid-extract	150	40	2,600	96	98
Acid-extract	150	40	2,690	96	98
Water-extract	150	40	2,600	92	98
Water-extract	150	39	2,515	93	97
Acid-ext., neutral	150	39	2,240	94	92
Acid-ext., neutral	150	45	2,360	92	92
Dilute acid	150	39	2,250	94	90
Dilute acid	150	40	2,200	94	90

A consideration of data submitted in Table VII shows that the acid-extract and water-extract gave somewhat larger loaves than the check, in the order named; and that with the acid-extract both color and texture were slightly improved. Fig. 1 gives some idea of the external appearance of the loaves.

TABLE VIII.—SERIES II—DURUM WHEAT.

Flour No. 481	Extract C.C.	Water C.C.	Volume Loaf C.C.	Color	Texture
Check	...	200	1,920	96	95
Check	...	199	1,870	96	95
Acid-extract	150	48	2,030*	96	94
Acid-extract	150	51	1,870*	96	98
Water-extract	150	50	2,010	95	96
Water-extract	150	51	2,030	95	96
Acid-ext., neutral	150	51	1,910	97	96
Acid-ext., neutral	150	51	....	..	..
Dilute acid	150	50	1,630	94	85
Dilute acid	150	50	1,650	94	85

*Baker's comment: "Dough broke slightly."

A consideration of the data submitted in Table VIII indicates but little improvement in loaf volume, color, or texture by the use of acid-extract. The water-extract gave better results than the acid-extract. The dilute acid decreases loaf volume and unfavorably modifies the texture.

TABLE IX.—SERIES II—VELVET CHAFF WHEAT.

Flour No. 993	Extract C.C.	Water C.C.	Volume Loaf C.C.	Color	Texture
Check	...	188	2,030	95	95
Check	...	187	2,060	95	95
Acid-extract	150	36	2,480	98	97
Acid-extract	150	36	2,460	98	97
Water-extract	150	36	2,340	94	96
Water-extract	150	34	2,200	94	96
Acid-ext., neutral	150	35	2,020	95	95
Acid-ext., neutral	150	36	2,040	95	95
Dilute acid	150	36	1,870	92	80
Dilute acid	150	36	1,700	92	80

As will be noted in Table IX, the acid-extract exerted a favorable influence on the baking qualities of flour from velvet chaff wheat, increasing the loaf volume, and giving a better color and texture. The water-extract increased loaf volume, but had little influence on color and texture. The dilute acid on the other hand had a marked unfavorable influence on loaf volume and texture, and, to a lesser degree, the color.

In view of the fact that in the larger number of baking tests the acid-extract had a greater influence than the water-extract to increase loaf volume and to improve the color and texture, the question naturally arises as to whether the improvement is due to the stimulating effect of acid, or phosphate, or other constituent of the extract on the yeast, or to some other factor. Experiments undertaken to determine the stimulating effect of acid-extract on yeast were not convincing. A possible explanation is that the gluten may have become more coherent in the presence of acid and soluble salts (particularly phosphates) as is suggested by Wood. At any

rate, the baking tests show clearly that it is not acid alone, but acid plus extractive material that gives the best results.

SUMMARY AND CONCLUSIONS.

In two series of baking tests of flour made from three varieties of wheat, acid-extract of bran, water-extract, acid-extract, neutralized and dilute acid, were used to replace a part of the water necessary to make the dough.

In general, the acid-extract produced larger loaves of bread (from 6 per cent to 20 per cent increase in volume) of a better color and texture than the check loaf, or those in which other extracts were used. The water-extract produced loaves somewhat larger than the check loaves. The dilute acid gave a loaf of decreased volume and very poor texture.

Analyses of acid- and water-extracts show the presence of 0.464 gramme P_2O_5 and 0.163 gramme P_2O_5, respectively, in 100 cubic centimeters extract.

Experiments made to show the stimulating effect of acid-extract on yeast were not convincing. It is thought the presence of both acid and soluble salts makes the gluten more coherent.

In general, the better the flour, that is, the stronger the gluten, the more marked is the improvement by use of acid-extract; but all samples of flour show greater or lesser improvement.

The inner portions of the loaves of bread made with acid-extract show no greater amount of water-soluble acid reacting material than the average of home-made or bakers' bread.

The Ascent of Lava*

The Propelling Force Due to Expanding Gases

By Frank A. Perret

WHY does the lava rise from below toward the earth's surface?

This fundamental question resolves itself, upon examination, into several parts. We may ask, for instance, why the lava should move in *any* direction—why, that is to say, there should be motion of translation in this material—why it should seek to extend itself from the position it occupies? But, whether by reason of the pressure to which it may be subjected, or through actual augmentation of its substance, or by the absorption of infiltrating materials, or even through greater fluidity resulting from some *lessening* of pressures, we know the magma to be endowed with the property and power of *expansivity*, in consequence of which it must, if possible, find or form for itself an outlet through its too restricting boundaries.

Nor, in view of this quality of expansiveness, shall we marvel that the magma should rise into a fissure which may open above the stratum or pocket which constitutes the reservoir. Assuming such injections to be abyssal, they will not, in general, perforate the outermost shells but, whether remaining as simple, lava-filled rifts or developing the expanded, top-like sections imagined by Johnston-Lavis[1] and Daly,[2] they will constitute secondary reservoirs nearer to, but not yet in communication with, the surface. It is from this point that the further progress of the lava forms the subject of our inquiry, why, of all possible directions, this should still be upward or, more precisely, outward from the direction of the earth's center toward its periphery?

Such further progress is effected, in general, by a progress of *trepanning*, so to speak, which results in the formation of a vertical tunnel, often of exceedingly small diameter in proportion to its length.

But, if we remember that the rising of the lava represents work against gravity and necessitates the perforation of successive strata, and that, furthermore, the progression takes place at the point farthest from the heat reservoir and where the actual contact pressure is least, it would almost appear, at first sight, that, in ascending as it does, the lava follows the path of greatest resistance and advances where its power to do so is most limited.

In seeking to explain these anomalies we may safely assume two things, viz., some guiding principle or directive force, which determines and maintains the upward direction of progress as a compass points to the north; and, second, some mode of action, some excavating agent other than simple heat and pressure, which has not yet been considered.

Beginning with the latter, we may ask ourselves if there is anything at the upper level, where the progression takes place, which is not to be found at the other contact surfaces? The answer is—gas.

We have here another demonstration, and a notable one, of the importance of the gaseous element in the dynamics of volcanic action. If the lava were a simple liquid and its function purely hydrostatic, as has sometimes been contended, the upward progression, as observed, could not occur. It is the escape of free gas which results, as we shall see, in the formation of the tunnel; but before taking up that phase of the subject, we may realize that we have also discovered the guiding principle, the directive force which determines and maintains the upward way. This lies in the *gravitative adjustment of gas and lava*—the gas, by its lightness, places itself above the lava and, constituting, as it does, the active boring agent, the direction of progression will and must be upward; nothing could be simpler.

As to the *modus operandi* of this trepanning by the gas-headed lava, it is obvious that we must consider the nature of the material to be perforated. If this consists of strata of solid rock the gases will be largely retained above the lava column as a small, compressed plug. Daly has pointed out[3] the powerful heating effect of such compression, by which the gas acquires a true fluxing power, melting the contact walls. The fused material absorbs gas, adding heat of solution and of chemical reaction. The gaseous head of the lava column thus becomes an effective means of progression, capable of fluxing its way through the hardest strata. Examples of this action on a small scale may be seen in the many little pit-craters at Kilauea, which are simple, cylindrical

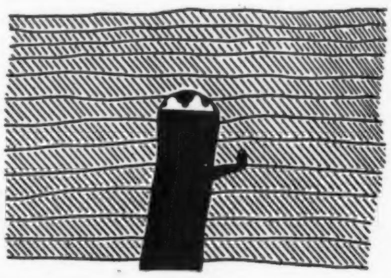


Fig. 1.—Lava column with compressed gaseous head, fluxing its way upward through solid strata.

channels rising vertically through the solid lava strata

If, on the other hand, the ascent of lava is through a conglomerate mass of more or less incoherent materials, it is certain that the gases cannot be so perfectly retained and compressed above the column of lava. In such a case their action will be excavative, disintegrative, corrosive. Channels will be enlarged, masses dislodged and engulfed; and this "stoping" process will be combined with the peculiarly destructive effects of *fumarolic* activity. In contradistinction to the former method of temperature development, this is here maintained by the *flow* of gas through the lava column, thus continuously bringing up heat from below.

In Fig. 2 the lava is represented as eating its way

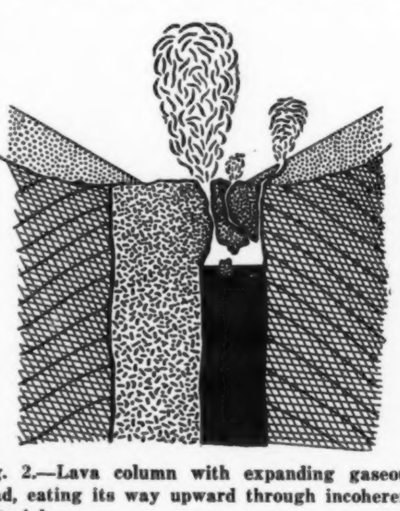


Fig. 2.—Lava column with expanding gaseous head, eating its way upward through incoherent material.

upward through the chaotic materials obstructing the conduit of a volcano as the result of the last eruption, the lava rising to re-establish communication with the crater and inaugurate a new eruptive phase after a period of repose. The sketch reproduces the actual condition of Vesuvius where, after seven years of external repose, during which time the conduit has been blocked, the lava has, at last, virtually reached the crater. Its gradual approach, by the process here described, has for many months been visibly manifested by a progressive increase in the temperature and volume of the fumarolic emanations at the crater bottom and especially by repeated *collapses* indicative of the subterranean stoping.

We may conclude that the progression of a lava column and its direction are determined by the gaseous emanation.

* Reproduced from the *American Journal of Science*.

[1] H. J. Johnston-Lavis: "The Mechanism of Volcanic Action," *Geological Magazine*, London, October, 1909.

[2] Reginald A. Daly: "Abyssal Injection as a Casual Condition and as an Effect of Mountain Building," *American Journal of Science*, September, 1906.

[3] Reginald A. Daly: "The Nature of Volcanic Action," Proc. Amer. Acad. Sci., vol. xlvii., No. 3, p. 93.

The Protection of Nature's Fauna

AS PRESIDENT of the French delegation at the International Conference of Berne for the protection of nature's fauna, M. Edmond Perrier, director of the Natural History Museum, has communicated to the Academy of Sciences the principal decisions taken at the conference. M. Perrier recalls the fact that, unless protective legislation be adopted by different countries, several species of animals will soon disappear. Thus, the large cetacea, such as the whale and cachalot, hunted excessively, especially by the Norwegian fishing societies, are doomed to rapid destruction. In ten years the rhinoceros and African elephants will also have disappeared unless the African hunting is put under control. The birds of paradise that are confined to New Guinea, a country not so large as England, and to the Solomon Islands, the extent of which is inferior to that of Corsica, are being veritably massacred. The aigrettes are undergoing the same fate. In presence of these facts, the conference under the presidency of M. Forrer, a Swiss federal councilor, has decided to name a permanent international committee, which will hold its sittings at Bâle, and will meet at least once every three years. Each country adhering to the conference will be represented by at least two delegates. Each delegate will submit to his government the proposals of the committee destined to bring about legislative measures in view of the efficacious protection of animals. Answering to a question of the secretary of the Academy, M. Darboux, M. Perrier added that the feather industry is trying to hinder all protective legislation. At the present time more than 50,000 workpeople are employed in plucking the skins of aigrettes, birds of paradise, and other birds. A feather worker earns about 4 francs a day to pluck 400 aigrettes. In face of the disappearance of aigrettes a feather merchant has appointed the Natural History Museum to award a prize of $2,000 to anyone who succeeds in the breeding of these birds. But it is hardly probable that the prize can be awarded in the limits appointed by the giver. From all accounts it appears that the feather industry is very prosperous, while, on the other hand, there are at present 30,000 artificial flower makers in Paris without work. The feather has killed the flower.—*Chemical News*.

Autumn Leaves

THE sumptuous gold and purple attire with which the autumn forests are bedecked has, for a very long time, been a problem. Many physiologists have wondered what is the nature of this coloration. Prof. Gaston Bonnier has explained, before the Academy of Sciences, the researches of M. Raoul Combes, who has been able to realize the production of the red substance of leaves outside the organism itself. Another scholar, M. Guilliermons, has studied the manner in which this red substance is produced from a histological point of view. The substance is produced by misochondries, those little living elements that are in the interior of all cellules. M. Raoul Combes has also shown that there exists in green leaves a yellowish substance, which he has isolated and crystallized, and it is this substance he has transformed into a red substance having identically the same point of fusion and the same properties as that which is extracted from reddened leaves. Now, it was supposed that this transformation took place under the influence of oxidation, but the proof was never given. M. Raoul Combes has shown that the contrary is the fact. It is by induction that the red substance is obtained at the expense of the yellowish substance of green leaves. It is easy to understand the importance of this question, for these researches are doubtless applicable to the coloration of all pink, violet, red, lilac, or blue flowers.—*Chemical News*.

The Sudden Origin of New Types—II*

By Felix Oswald, D.Sc., B.A., F.G.S.

Continued from SCIENTIFIC AMERICAN SUPPLEMENT No. 1984, Page 27, January 10, 1914

IN the case of mammals it is obvious that their sudden rise and predominance in the Tertiary epoch, supplanting the reptiles in every branch of life, must have been due to the rapid development of some part or parts of their organization, which gave them a distinct and overwhelming advantage over their reptilian competitors in the struggle for existence. It is true that the brains of the great Dinosaurians, so far as our evidence goes, are remarkably small in comparison to the size of the animals, and show a low and simple state of organization; but the larger and more complex brain does not appear to be the primary factor, although doubtless it was an important element in assuring the predominance of mammals. The primary and determining point of difference between reptiles and mammals obviously lay in the adoption by the latter of mammary glands for nourishing their young; all their other advantages can be derived from this essential feature. The suckling of the young with a perfect food like milk entailed a longer association with the mother, while permitting a more gradual attainment of maturity. These factors, together with the greater maternal sacrifice entailed by lactation, would in themselves be sufficient to promote and foster a greater development of brain in mammals than in the case of reptiles, in which the young individual has no other start in life than the yolk within the egg prior to hatching. The acquisition of warm blood and of a hairy covering are probably to be regarded merely as secondary consequences of a general advance in organization resulting from a novel mode of nutrition of the offspring and the concomitant advantages of a lengthened period of development.

Now, the question naturally arises: Were the mammary glands absolutely new structures, or were they modified from pre-existing glands? The latter hypothesis is *a priori* more probable and more consonant with the usual laws of development of organs. The mammæ form of repetition of similar structures, ranged in series along two convergent lines, extending from the axillæ toward the pubic bones. Even in man supernumerary nipples have been shown to occur along these mammary lines in 90 per cent of the observed cases. It is a curious circumstance that the abnormal presence of these structures is more frequent in men than in women; this fact alone would lead one to surmise that mammary glands were originally derived from structures which were at least as equally developed in the male as in the female. It is also noteworthy that the percentage of supernumerary mammæ is higher than would naturally be suspected, for Bardeleben[14] found that out of nearly 3,000 recruits as many as 23.3 per cent possessed additional teats. In many species of mammals the number of the mammæ is indeed very inconstant within the limits of the species.

The mammary glands are usually regarded as modified sebaceous glands, but this opinion does not go far toward solving the question of their origin from a phylogenetic point of view. At this juncture embryology comes to our aid and throws unsuspected light upon the problem. Thus O. Schultze discovered that in the young embryos of several mammals (pig, rabbit, etc.) a dorso-lateral ridge is formed on each side, and that the mammæ and nipples are eventually developed at points upon this ridge. By subsequent changes of growth these two dorso-lateral mammary lines are finally brought down into the ventro-lateral position that is permanent in the adult. Now the dorso-lateral position of these lines in the embryo exactly corresponds to the position of one of the lateral lines in Amphibia;[15] it seems to me therefore within the range of probability that by the very common occurrence of a change in function the lateral line has become transformed into the mammary line in the course of evolution from amphibians to mammals, and has subsequently become differentiated into separate mammæ. The glands in both cases are similarly situated and in both cases arise in the Malpighian stratum of the derma.

Even at the present day the small, heterogeneous remnant of the Urodele Amphibians shows considerable diversity and variety with regard to the glands of the lateral line. In some cases these glands secrete a milky juice, although this appears to be of a poisonous nature. It is therefore conceivable that in some of their remote ancestors corresponding glands may have taken to secreting a milky fluid capable of nourishing their young. As soon as this change of function had become established, it would obviously be more convenient and advantageous for the nutritive organs firstly to travel from a dorso-lateral to a ventro-lateral position, and secondly to become reduced and concentrated in a few centers along these lines.

It will now be evident that the same principle which has been discussed in the case of the ancestry of flowering plants can be held to apply to the origin of mammals. Thus we find in the first place a lateral line (or more than one) composed of a repetition-series of similar glands—a condition which is in itself conducive to a high degree of variability of the members of the series. Under special conditions one or more of the variations might have progressed in the direction of the glands producing a nutritive secretion; when once this initial step had been taken all the subsidiary characters of

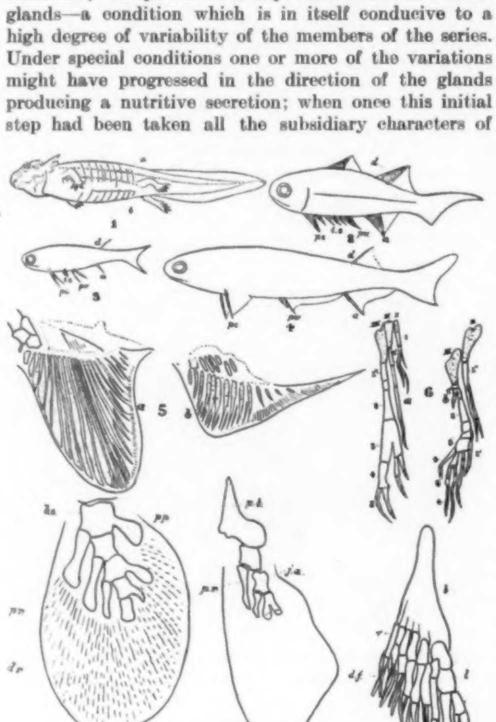


FIG. 1.—Salamander larva. *a, b,* lateral lines. FIG. 2.—*Climatius scutiger,* Agerton. *pc,* pectoral; *pv,* pelvic; *a,* anal; *d,* dorsal fins; *i.s.,* intermediate spines. FIG. 3.—*Mesacanthus mitchelli,* Egerton. Lettering as in Fig. 2. FIG. 4.—*Acanthodes sulcatus,* Ag. Lettering as in Fig. 2. FIG. 5.—*Cladoselache.* *a,* pectoral; *b,* pelvic fin. FIG. 6.—*Pleuracanthus* (*Henacanthus*) *Decheni,* Gf. *a, b,* skeleton of anal fins; I, II, III, hæmal arches; 1-6, segments of fin-radials. Right border pre-axel, left border post-axial. FIG. 7.—*Glyptolepis* (*Holoptychius*) *leptopterus,* Ag. Endoskeleton of the second dorsal fin. *b,* basal; *r,* radial; *l,* segment of a longitudinal axis; *d.f.,* traces of dermal fin-rays. FIG. 8.—*Eusthenopteron Foordi,* Wbt. *a,* left pectoral fin; *b,* pelvic fin; *b.s.,* basal segment of axis; *p.p.,* post-axial process (radial?); *p.r.,* pre-axial radial; *d.r.,* dermal rays; *p.b.,* pelvic bone; *j.a.,* jointed axis.

the Mammalia could easily have followed as a natural consequence. Among the chief of these was the increase of intellect, which is well known to vary directly as the maternal sacrifice. As a necessary corollary to the absence of the lateral line in all reptiles, it is evident that—contrary to the received and prevalent opinion—mammals must have taken their origin directly from Amphibia, not from Anomodont reptiles, which were already highly specialized creatures and should be more naturally regarded as a closely parallel side-branch from a common ancestral amphibian stock. The earliest mammals must have been smaller and more generalized in structure than the Anomodonts. Indeed most attempts at representing the true phylogenetic relationships of animals suffer from the stem-form not being placed far enough back in the line of ancestry. On the other hand, the lateral line was well developed in the adult Stegocephalan amphibians, with the exception of the Aïstopoda.

As an instance of the manner in which reduction in one direction may have an influence upon the growth and differentiation of quite another part of the structure of an organism, attention may be drawn to the dependence of the increase of brain capacity in mammals upon the adoption of a hairy covering consequent on the reduction and final abandonment of scales. To this may be attributed the formation of the neopallium, which G. Elliot Smith[16] explains by the fact that "in the immediate ancestors of mammals the number and variety of sensory paths which found admission into the cerebrum became enormously increased, and led to a further specialization of the pallial formation, resulting in the birth of the *neopallium*—a cortical area where all the sensory impulses brought to the cerebral hemispheres along these new channels might be received, be blended in consciousness with those coming from other sense-organs, and leave impressions which might be stored, as it were, in this neopallium, and so influence other sensations and states of consciousness at some subsequent time. The neopallium is thus the organ of associative memory." And he also states that "the first appearance of a definite neopallium coincides with the transformation of the skin over the whole surface of the body into a highly specialized tactile organ." This conclusion may even be carried still further, as Friedenthal has pointed out, to explain the great development of the brain which is obvious even in the earliest human skulls. Thus, by man becoming naked, owing to the hair being reduced to a minimum, the skin became more than ever before the seat of the reception of tactile impressions, and thereby the extent of the neopallium became increased, and the mentality of the human race correspondingly enlarged.

The theory of the evolution of limbs in the Vertebrata from continuous fin-folds (extending along the entire length of the body), which is now so generally accepted, furnishes another instance of the general principle of this paper. The paired fins as well as the unpaired fins appear first of all as longitudinal folds of the body-wall; in the Elasmobranch embryo each somite gives rise to a fin-element, consisting of two rods of cartilage (somactidia), with two dorsal and ventral bundles of muscles, each supplied by a spinal nerve. These fin-elements disappear except in the pectoral and pelvic regions, where a considerable number of these outgrowths are concentrated, and unite to form the pectoral and pelvic fins respectively. Now here we find an instance of a great number of similar structures (somactidia or segmental radials) in the fin-fold; as a result of this multiple repetition there naturally ensues a high degree of variability, and the first step in the successful variations consisted in the breaking up and reduction of the continuity of the fin-folds into a series of paired fins, forming a double series along the entire length of the abdomen. Some of these earlier fins, lying between the pectoral and pelvic fins, became reduced to mere spines, which Smith-Woodward[17] regards as the stiffened front-edges of such fins, e. g., in the Acanthodian *Climatius scutiger*, Egerton, and *Mesacanthus Mitchelli*, Egerton, of the Lower Old Red Sandstone (Figs. 2, 3).

The next stage, following the differentiation of the continuous fin-folds into separate fins, was that in which the fin-flaps attained greater rigidity by the concrescence of the bases of the somactidia at four nodal points. Now the ceratotrichia are supported by tri-segmented radial cartilages (pterygiophores). This primary number *three* is of considerable significance, for the pentadactylate limb is essentially composed of three segments, the foot being regarded as the distal segment, which has become still further segmented secondarily. In Cladoselache—the most primitive form with regard to the appendicular limbs—this tri-segmented nature of the fin is clearly visible, but even here some reduction has evidently taken place in comparison with the simpler arrangement still visible in the unpaired fins of living Elasmobranchs. In the pectoral fin of Cladoselache (Fig. 5) the elements of the basal segment have become fewer and stouter, by fusion due to growth-pressure, so as to form a basal support (basipterygium), and the distal elements have become more slender and reduced in number. But no trace of pelvic girdle was developed in Cladoselache, and the pectoral girdle did not proceed beyond the basipterygial stage.[18] The limb-girdles, which show great variations in form, are clearly adaptive structures, and were apparently segmented off from the proximal radials or basipterygium; and although limb-girdles are present in the more specialized, but still very primitive Pleuracanthus, the two halves of the limb-girdle remain distinct. In proportion to the exigencies of an increased demand for support and leverage for the fins, the limb-girdles increased in size by dorsal and

* *Science Progress.*

[14] Quoted by Bateson, *Materials for the Study of Variation*, London, 1894.

[15] Additional force is lent to my theory by the fact that there are several lateral lines in Proteus and all Amphibian larvæ (Fig. 1), not only a dorso-lateral but also an axillary-inguinal, exactly corresponding in position to the mammary line.

[16] Some Problems relating to the Evolution of the Brain. Arris and Gale Lectures, Roy. Coll. of Surgeons, 1909.

[17] Presid. Address, *Proc. Geol. Assoc.* xix. 1906.

[18] R. C. Osburn, "The Origin of Vertebrate Limbs," *Ann. New York Acad. Sci.* 1906-7, has shown that in Cestracion the rays and basals begin to appear before the girdle, and this is supported by the palæontological evidence of Cladoselache. But all three structures are differentiated out of the same band or layer of mesenchyme.

ventral out-growths, and subsequent union in the median plane. It is, however, only in Elasmobranchs and Dipnoi, not in Crossopterygians, that actual union and fusion of the two halves take place. Not until this stage had been reached, giving a suitable amount of support, could fins or paddles become adapted, by further specialization and reduction, to the optimum necessary for crawling on the sea-shore.

It may be remarked parenthetically that in *Pleuracanthus* the anal fins (Fig. 6) which may have some use for crawling on the sea-bottom, show, if anything, a more superficial resemblance[19]—by a variable fusion of radials—to the pentadactylate limb than the pectoral and pelvic limbs do; and since this is the case in a fish which is so generalized a type that it might "with very little modification become either a Selachian Dipnoan or Crossopterygian,"[20] it furnishes us with a possible clue as to the *analogous* way in which the pentadactylate limbs could become differentiated from the paired fins. A marked reduction is also to be seen in the dorsal fin of the Crossopterygian *Glyptolepis* (almost handlike) (Fig. 7), in which the proximal radials are united at their base into a single piece—the basipterygium—but are free distally.[21]

In Elasmobranchs and Crossopterygians[22] the basal elements of the paired fins remain three in number, pre- meso- and meta-pterygium, but a rapid reduction must have been correlated with the adaptation to progression on land (doubtless due to the mechanical necessities of raising the body above the ground) so as to reach the typical reduction characteristic of the Tetrapoda, viz., to the single basal element, the double median element and the pentadactylate distal portion, which is to be seen, already in Carboniferous times, in such diagrammatic simplicity in the Stegocephalan limb, e. g., Seeleya. At any rate pentadactylism is a special instance of a very rapid reduction to a minimum optimum. The horny fin-rays would conceivably coalesce at the same time to form epidermal claws protecting the tips of the distal radial elements of the limb. Thus there was a steady system of progressive reduction until the Amphibian type was reached.

Just as a rapid reduction followed the adaptation of fins for progression on land, so conversely when higher Vertebrates have returned to an aquatic mode of life, the opposite tendency is exhibited of extra or supernumerary digits being formed adaptatively on the post-axial side of the limb. In the White Whale or Beluga (Delphinapterus) this increase has been secured by a longitudinal division of the fifth digit, and a splitting of the digits took place in Ichthyosaurus. Hyperphalangism, or the formation of additional phalanges, is clearly shown in aquatic reptiles (Plesiosaurus, Ichthyosaurus) and also in mammals which have become adapted to progression in water (Globicephalus and other Cetaceans). In the Manatee (*Manatus americanus*) Vaur has shown that an extra (fourth) phalanx develops adaptively on the third digit during the growth of the individual under mechanical influence, while the embryos possess only the usual three digits. The same tendency is exhibited by Chelonia, e. g., in the *Trionychoidea*, in which the fourth digit in each limb never has less than four phalanges; in addition the members of this group are losing their claws, which are unnecessary for fin-like structures, only the three inner digits being provided with them. In Carettochelys of New Guinea only two of the elongated digits possess claws; in the adult Loggerhead (*Thalassochelys caretta*) only the claw of the first digit remains.

It is noteworthy that the paddle-finned fishes with Amphibian affinities, both the Crossopterygii and the Dipnoi, reached a very great development in the Middle and Upper Devonian, probably as a result of the severe desert-conditions of the Old Red Sandstone, when the fishes of the evaporating seas and lagoons were forced either to become adapted to an amphibian existence or to perish miserably from suffocation and starvation. The exigency of crawling on the mud by means of paddle-fins would soon result in the evolution of an elbow-joint, just as it has done at the present day in the case of the Hopping Gobies (Periophtalmus and Boleophthalmus) of the tropical mangrove swamps or the somewhat similar blenny Alticus, which is also adapted for progression on land.

One of the clearest instances of the principle set forth in this paper is exemplified by the sudden rise of the Hydrozoan class of Graptolites.[23] The oldest form is the branched, tree-like Dictyonema, occurring in fanlike or funnel-shaped colonies. It appeared first of all in the Cambrian of the Appalachian Mountains, and—as in many other characteristically Silurian groups—a general eastward migration gradually took place, so that Dictyonema is found at a somewhat later date in Northern Europe; in the Baltic Region it is found immediately overlying the Obolus-conglomerate of the uppermost Cambrian.

Other early forms of the *Dendrograptidi* (*Dendroidea*) or dendroid Graptolites are Dendrograptus (e. g., the dichotomous *D. Hallianus* of the Potsdam Sandstone), Callograptus and Ptilograptus; in all of these branched fixed forms, with uniserial hydrothecæ, no virgula occurs. Dictyonema, however, which lasted from the Upper Cambrian to the Middle Devonian, showed remarkable and unusual persistence for this class of organisms, perhaps owing to the fact that it may not have grown on the sea-bottom like its nearest relatives but was probably a freely floating colony, since it terminates basally in a sicula attached to a long thread[24] (nema). The repetition-series of the numerous branches and the closely repeated hydrothecæ of the *Dendrograptidi* constituted the preliminary developments, which by themselves were sufficiently to induce a great amount of variability. It is therefore not surprising that the true Graptolites arose so suddenly and devoloped so large a variety of forms, particularly since their ascendance into a numerous and successful class was associated with the change from a sessile, littoral habit (though perhaps attached to seaweeds) to an exclusively pelagic, freely floating or even swimming mode of life. This change was correlated with special adaptations such as air-bladders (pneumatophores) and possibly even swimming membranes (Dichograptus).

The earlier of the true Graptolites such as *Bryograptus* of the Upper Cambrian (Tremedoc) among the *Dichograptida* or *Axonolipa*, are repeatedly branched, and as their evolution proceeded we see the inevitable reduction and specialization in different directions rapidly taking place. The *Dichograptidi* stand nearest to the dendroid Graptolites and resemble them in possessing no virgula and in the hydrothecæ being back to back; the extent of branching has already become reduced in Tetragaptus and Loganograptus. Even in this group a still further reduction has taken place from diprionidian to monoprionidian forms; in the later and still more specialized order of the *Axograptidi* or *Axonophora* (which, however, possesses a virgula giving greater rigidity to the Polypary) this reduction is still more pronounced. Sometimes it even becomes evident in a single individual colony, as in Dicranograptus, in which the polypary is at first diprionidian but soon divides distally into two monoprionidian branches.

It is in consonance with the principle discussed in this paper that the progressive simplicity exemplified by the reduced extent of branching, as well as by the reduction of the series of hydrothecæ from a double to a single row, goes hand in hand with an increasing specialization and complexity of form of the hydrothecæ. The earlier hydrothecæ were straight and possessed straight apertures; as time proceeded the apertures became curved and were often produced in a spine, while in the Silurian period they attained even greater complexity. Moreover, the specialization of the latter forms with regard to the pelagic habit is exhibited not merely by the Upper Silurian Diplograptus, with its pneumatophores, but by Retiolites with its netted periderm. The latter structure is an adaptive device in the direction of lightness combined with strength, which is met with again, for instance, in the pelagically specialized swimming Crinoid Saccocoma of the Jurassic.

The continuous evolution of one generic type from another is particularly well shown by graptolites and is therefore of great value in its bearing upon my theory. It is clear also that the expression of a Graptolite genus differs widely and essentially from the ordinary conception of the term. Thus, since the same type of hydrotheca is found in three successive forms *Bryograptus reflexus*, *Tetragraptus denticulatus* and *Didymograptus fasciculatus*, it is considered that they stand to each other in direct genetic succession and exemplify a progressive specialization from the original much-branched form. A similar conclusion is reached in the case of the successive series *Bryograptus Callavei*, *Tetragraptus Hicksi* and *Didymograptus affinis*, which all agree in possessing in common another type of hydrotheca. Furthermore, since the species of the genus Monograptus, as at present constituted, exhibit a great variety of hydrothecæ, it is evident that this genus is polyphyletic and is merely a convenient conception for signifying that divergent branches in the genealogical tree of the graptolites reached a similar stage of evolution at the same period.

Among Echinoderms the general principle discussed in this paper can also be detected, although the origin of the class as a whole must have taken place in pre-Cambrian times and is consequently beyond our ken. Stalked Cystoidea belonging to the primitive bilateral CARPOIDEA (showing an absence of the characteristic pores of Cystids) are already known from Cambrian rocks, e. g., *Trochocystites bohemicus* Barr. (Mid-Cambrian of Bohemia); hence the sessile Aristocystis of the Ordovician of Bohemia, which is usually regarded as a very primitive form, can only dimly indicate to us the ancestral forms (the AMPHORIDEA) of the extremely heterogeneous and diverse assemblage of Cystids. Aristocystis has probably undergone some simplification and reduction, especially in the matter of the absence of arms and ambulacra. Yet it still shows primitive characteristics in the repetition of similar parts (which is capable of inducing exuberant variability), e. g., in the numerous plates without definite orientation which form the sac-like body, with an undifferentiated and indefinite porous structure of the stereom. Even the Cambrian Trochocystites among the CARPOIDEA shows some specialization in the ring of large plates encircling the planoconvex calyx, which is otherwise composed of an indefinite number of small plates (larger, however, on one side than on the other). Here a primitive bilateralism has been retained and emphasized, and although the CARPOIDEA are stalked forms, yet radial symmetry has not resulted from the adoption of a stem for a sessile habit. Indeed, since the short, pointed stem is hollow and plated it is not improbable that it was adapted for a balancing or directive function rather than for the purpose of fixation.

As soon as a stalked habit had become general a tendency toward pentamerism must have rapidly made itself felt, for as I have already explained with regard to the prevalent pentamerism in flowers, it can be derived for geometrical reasons from the exigency of combining economy of material with the attainment of the greatest amount of enclosed space.

A progressive reduction and specialization can be traced in the Cystids; among the DIPLOPORITA, Glyptosphærites shows a distinct advance in type upon Aristocystis in the pentamerism of its ambulacral grooves. Its polygonal plates, however, are still numerous and irregular and the diplopores are irregularly arranged. This is also the case in the earlier DICHOPORITA as exemplified by Echinosphærites. In this group the pores are definitely arranged in pore-rhombs, and it contains transitional forms leading up to the Blastoids and Crinoids, both of which afford clear instances of a rapid reduction from the indefinite number of plates of the early Cystids to a strict pentamerism of the calycal plates. The Blastoids have been shown by Jaekal to be derived from the Dichoporite division of the Cystids by an ever-increasing regularity in the orientation of the food-grooves, by their closer structural relations to the theca and in the more perfect development of basals and radials. It will be noticed that in the early ancestral forms, such as the Silurian Cystids Proteroblastus or Mesocystis, we meet once more with a pronounced multiplicity of parts, in this case consisting of an indefinite number of interradial plates and the irregularly scattered diplopores. From these forms the earlier Blastoids, such as the Ordovician Asteroblastus and Blastoidocrinus (sometimes classed separately as PARABALSTOIDEA), seem to stand in close genetic relation; among other transitional characteristics their radials are not forked and numerous small plates are intercalated between the radials on the one hand and the large deltoids and ambulacra on the other hand. The Blastoids, however, appear to have suffered from a rapid over-specialization and excess of regularity and were consequently unable to survive the rigorous changes of conditions at the close of the Carboniferous period, which proved fatal to so many of the older types of animals.

Pentamerism had also appeared already in certain Crystids, e. g., Echinoencrinus among the DICHOPORITA, which are closely related to the ancestral Crinoids; and a distinct transitional series to the regular pentamerism of Crinoids has been traced in the *Caryocrinidæ*, from the Ordovician Hemicosmites to the Silurian Caryocrinus, which exhibits close affinities to monocyclic adunatea Crinoids such as Hexacrinus of the Middle Devonian. At the same time there is a concomitant reduction of the numerous brachioles to the usual five arms of Crinoids.

Pentamerism was no less well marked in Crinoids than in Blastoids, but the plates of the calyx retained a more uniform and generalized character than the highly specialized deltoids and forked radials of Blastoids. In many cases, however, a still further reduction in number took place in Crinoids, especially in the dicyclic forms, in which the infrabasals may be reduced to four, or more usually to three, upon which the five basals are superposed. Even the basals in the dicyclic forms become also subjected to a reduction to three, evidently for the purpose of giving greater strength to the calyx; but the radials of course always remain five in number, corresponding to the Invariable and

[19] A. Fritsch, *Fauna der Gaskohle*, 1883-1901.

[20] A. Smith-Woodward, *Vertebrate Palæontology*, 1898.

[21] A. Smith-Woodward, *British Museum Catalogue of Fossil Fishes*, 1891.

[22] In the Crossopterygian *Eusthenopteron Foordi*, Wht. Fig. 8, of the Upper Devonian of Canada (Whiteaves, *Trans. Roy. Soc. Canada*, vi. 1888; and Goodrich, *Quart. Journ. Micr. Sci.* xiv. 1901) the pectoral and pelvic limbs clearly show a reduction of the basal radials to a single element, supporting two elements (one of which is regarded as a pre-axial radial), but at any rate this arrangement gives us a strong hint of the Tetrapodan type.

[23] It is necessary, however, not to lose sight of the circumstance that the relation of the Graptolites to the Calyptoblastoid Hydrozoa is no longer universally accepted. The appearance of Diplograptus with its central plate (pneumatophore) partly covering a series of vesicles (gonothecæ) from the base of which the hydrorhabds radiate outwards has led to the suggestion that the Graptolite colony was a Medusa-like organism, and that the hydrorhabds were its tentacles.

[24] This is true for *D. flabelliforme*, Eichw.; in *D. cavernosum*, Wiman, however, an adhesive disk is present.

constant number of the arms. Infrabasals no longer occur so frequently nor are they so well developed in the Mesozoic as in the Palæozoic Crinoids; and they are obviously undergoing reduction in the Mesozoic forms.

Turning to the Echinoids, it is evident that the Palæozoic forms represent a plastic and fluctuating stage of transition in the evolution of the phylum. The inconstancy of the number of the rows of plates of the corona, and the flexibility (in most cases) and variety of form of the test, with its fragile, thin, and loosely articulating plates, which occur in the earliest Echinoids in comparison to the Mesozoic genera, are characteristics which present an analogy to the manifold variety of forms exhibited by most groups near their point of origin, just as we have already seen to be the case in the Mesozoic *Bennettiteæ*, just before a reduction to a working optimum had been arrived at by the early Angiosperms. The Palæozoic Echinoids displayed a tentative variability in various divergent directions, and the Cidaroids alone out of all these offshoots from the parent stock survived to perpetuate the race. From the CIDAROIDEA all the Mesozoic and modern Echinoids can be derived.

Although the Ordovician Bothriocidaris is at present the oldest known Echinoid, it is probable that its single row of plates in each interambulacrum and its rigid test represent an early experiment in reduction. On the other hand, in view of the multiple and inconstant number of rows in the interambulacral areas in other Palæozoic Echinoids such as Archæocidaris, Melonechinus (Melonites), Palæechinus, etc., the latter state of things should presumably be regarded as the more primitive feature. This is all the more probable, seeing that in post-Palæozoic forms the reduction to the optimum of two rows in each area has become a constant characteristic.[35]

Among the earliest forms a fairly near approach to the Cystids seems to be made by *Echinocystis pomum* of the Upper Silurian, in which the flexible test is composed of a mosiac of numerous (10 in the diameter) irregularly arranged and undifferentiated interradial plates with small spines, each ambulacral area containing four rows of pore-plates united at the upper pole without forming an apical disk. In Palæodiscus (also from the Lower Ludlow Shales) a close approximation, on the other hand, is made to the Starfishes, for a series of ambulacral plates like those of the ASTEROIDEA occurs inside the plates of the corona, and the tube-feet in the oral portion of the radii apparently passed out between the outer ambulacral plates, but the chief radial water-vascular vessels seem to have run along inside the test; the radioles or movable spines are small and do not differ very greatly from those of some EDRIOASTEROIDEA and ASTEROIDEA.

In the Devonian Lepidocentrus—the earliest and most primitive of the Cidaroidea—the test is flexible and this flexibility is still retained to a less extent in the Lower Carboniferous Archæocidaris in which there are 4–7 rows of large overlapping plates in each interambulacral area and two rows of ambulacral plates. Olioporus has four ambulacral and 4–9 interambulacral rows, while in the Carboniferous Melonechinus (Melonites) there may be as many as 4–11 columns of interambulacrals and 5–14 ambulacrals; in Lepidesthes there are 8–18 ambulacrals and 3–6 interambulacral rows; in Palæechinus (also Carboniferous) there are respectively 5–7 rows of interambulacrals, decreasing in number toward the poles and only two rows of ambulacrals. It is evident that (with the exception of the aberrant Bothriocidaris) the reduction to the optimum of two rows took place with greater rapidity in the ambulacral areas than in the intervening zones. The reduction in the number of plates went hand in hand with an increased rigidity and consolation of the test as a whole, and an increase in the size of the spines.

If, as now seems likely, the Echinoids took their origin from an early offshoot of the Asteroids rather than directly from the Cystids, this would all the more point to the significance of a multiple repetition of similar parts in inducing the evolution of numerous divergent variations; Macbride has suggestively remarked that "when we recollect that some of the oldest ASTEROIDEA known to us had very narrow arms and interradial areas edged by large square marginals, it does not require a very great effort to imagine how these marginals could be converted into the vertical rows of the interambulacra and the pointed narrow arms, becoming curved, could have formed the ambulacra."

In the organization of the PELECYPODA we find a feature which has admitted of an almost inconceivable amount of variety, both of form and arrangement, viz., the manner of the hinge-attachment between the two halves of the shell. It is a matter of some significance for the theory of this paper that the most primitive of the PELECYPODA are those forms which exhibit the Taxodont type of hinge, in which the interlocking, comb-like teeth are numerous and similar in size and form. The primitive nature of the Taxodont class is clearly evidenced by the fact that the embryo shells of many of the higher forms (*Ostreidæ*, *Pteriidæ*, *Philobryidæ*, *Mytilidæ*, etc.) pass through the Taxodont stage of a more or less rectilinear or gently curved hinge-line with a considerable number of teeth; and that in still higher forms (*Condylocardia* and *Scioberetia*) this Taxodont stage, "present in the early embryo, is succeeded by the series of folds (characteristic of the young stages of the higher Pelecypods) that subsequently divide off into cardinal and lateral teeth, thus linking the Taxodont with the Heterodont and Desmodont types of hinge."

Although considerable differentiation must have already occurred in pre-Cambrian times, yet the Taxodont shells (Ctenodonta = Tellinomya, Glyptarca, Redonia) are relatively numerous in the Cambrian period in comparison with the higher and more differentiated forms, e. g., Modiolopsis, and even in the Lower Ordovician a nearly similar disproportion is in evidence. It is therefore apparent that Pelecypods started with a Taxodont hinge; owing to this repetition-series of similar teeth a high degree of variability must have ensued, followed by a rapid reduction to an optimum, i. e., to the Heterodont form of a cardinal tooth and two lateral teeth. Increased specialization has led to still further reduction or even complete suppression. The existing genus Nucula is one of those rare instances which have retained many really archaic characteristics, not only in the nature of its hinge-line, but still possessing the primitive Aspidobranch type of gills, the primitive creeping foot and the nacreous type of shell. In the Palæozoic forms of the *Nuculidæ*, however, the ligament is mostly external, while in the recent forms it occurs internally, below the umbo. It is probable that *Tellinomya pectunculoides* of the Ordovician, with its equilateral, nearly circular form of shell, its curved hinge-line, equal adductor-impressions and semicircular, simple pallial line, stands very close to the ancestral form, and that the *Arcidæ*, with the straight hinge-line, formed an early specialization.

(To be continued.)

[35]The Cretaceous *Tetracidaris* has indeed four rows of plates to each interambulacrum but they are reduced to two rows at the apical region.

Ports on the North Pacific

THE changes wrought in the geography of the world by the construction of the Panama Canal, and the consequent changes to be expected in the world's commerce, involve preparations in the form of new harbors, new docks, and additional railways, remarkable alike in extent and in rapidity of construction. Contemplated as a whole, and when the element of time is taken into account, these undertakings constitute an engineering project of variety and magnitude unprecedented in the history of transport development. Nature has been exceptionally kind to builders of ports and harbors on the North Pacific coast, and the statement of conditions in regard to such favored ports as Vancouver, Prince Rupert, and Puget Sound, may well excite envy along less favored coasts.

The dual character of the transport problem is clearly revealed in this awakening of the Pacific trade, for engineers must there concern themselves with difficulties presented by the hinterland and balance them against the advantages of ready-made channels, anchorages, and deep-water basins of natural formation. They must think, in fact, in terms of heights and distances, chains and levels, as well as in terms of tides, fathoms, and quay facilities; for the massive mountain ranges that border the Pacific present an old task in an extended and accentuated form to railway engineers, and all the resources of modern contractors will be requisitioned in the friendly struggle which is now to begin between the Pacific ports for the new trade. Special attention may be directed to the port of Portland with its quay development parallel to the current in contrast to slips or piers projecting into the stream, partly because the works on the bar are ranked among the greatest of the kind ever constructed, and partly because of the probability that in the more or less distant future parallel quays will characterize the development of such ports as London.—*London Times.*

Aluminium as Flux

By Robert Grimshaw

IRON founders have long known that aluminium is an excellent flux. It oxidizes very easily and removes oxygen from the cast iron and steel, according to the formula $Al_2 + O_3 = Al_2O_3$, evolving 391,000 calories, an amount of heat sufficient to raise the temperature of one kilogramme of iron 1,400 deg. Cent., or one pound 5,545 deg. Fahr. This heat causes the sudden foaming of the mass. The energetic movement noticed in the pouring ladle brings the molecules in contact with air, which produces iron oxide; but this oxidation can be avoided by covering the melted iron or steel mass with sand or charcoal. If the melted metal does not attain a high temperature the effect of the addition of aluminium is almost *nil*. The amount of fluxing metal necessary depends on the quality of steel and the purpose of the casting. For steel with 0.5 per cent carbon there should be added from 160 to 320 grains of aluminium per ton, while for a higher carbon steel only 150 to 250 grains are necessary.—*Journal of the Franklin Institute.*

A Mnemonic Rule for the Value of the Constant π

THE following French verse is given by Dr. Gerhard Kowalewski in his text-book of calculus as a mnemonic rule for remembering π to 30 decimals.

"Que j'aime à faire apprendre un nombre utile aux sages!
Immortel Archimède artiste ingénieur
Qui de ton jugement peut priser la valeur!
Pour moi ton problème eut de pareils avantages."

It is much easier to remember these verses than the numbers, derived from counting the letters, of each word, namely—

3.141592653589793238462643383279.

Perhaps some of our readers may want to try their skill at working out an English version.

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